The Missing Pages In This
Volume Are Advertisements

Concrete

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A Review of the 1926 Accomplishments in Concrete Pavement Construction

Biggest Concrete Pavement Year on Record—Street Yardage Shows Increase—Wide Highways Occupy Attention of Planners—Thickened Edge Design Continued—New Construction Methods Described—High Early Strength Concrete Placed in Pavements—Shorter Curing Period Used—Plans for the Future

By O. A. STELLER

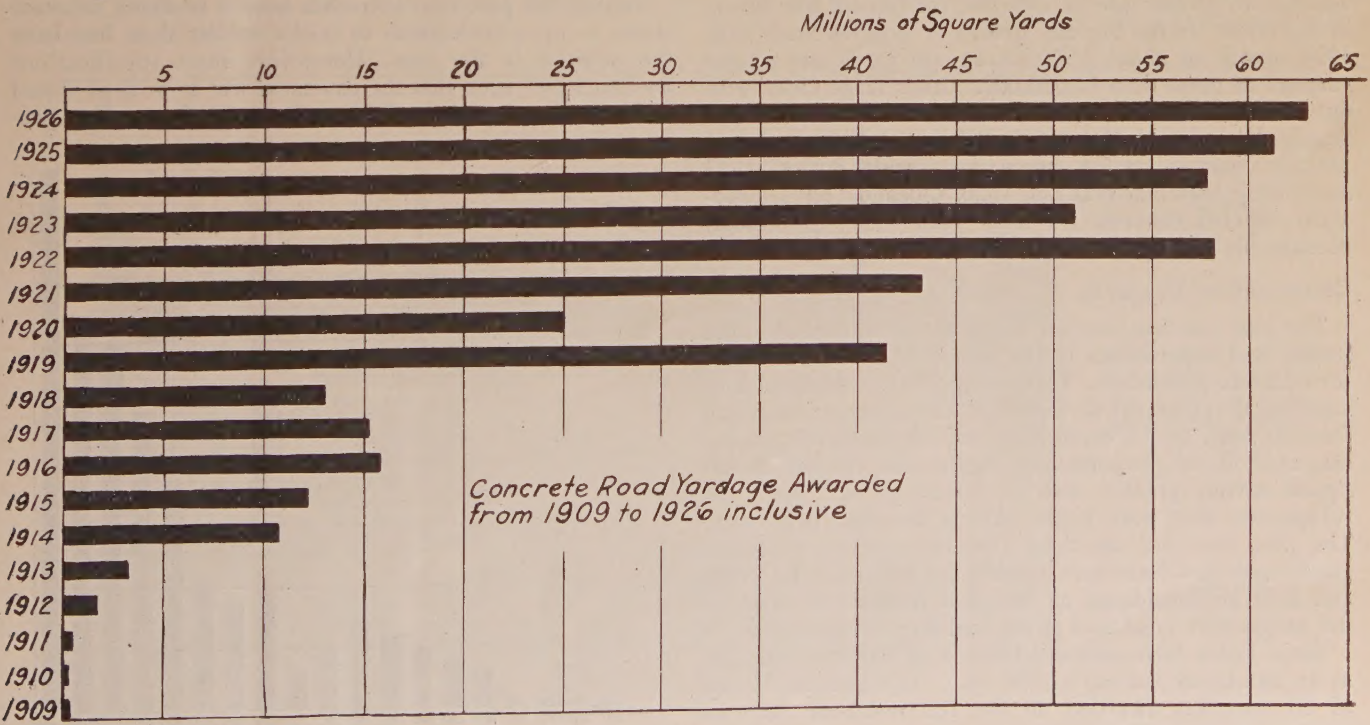
CONSTRUCTION activities during 1926 broke all previous records, involving as they did, a total expenditure of about 7½ billion dollars. In the concrete pavement field, a similar record was attained. With awards totaling around 110,000,000 square yards of concrete pavement, the previous record year—1925—was exceeded by about 6,000,000 square yards. Highway awards were approximately equal to last year. The increase was due to greater volume of concrete pavement yardage placed under contract in American cities.

Accompanying charts show the yearly gains in concrete pavement yardage for both road and street awards.

Records by States

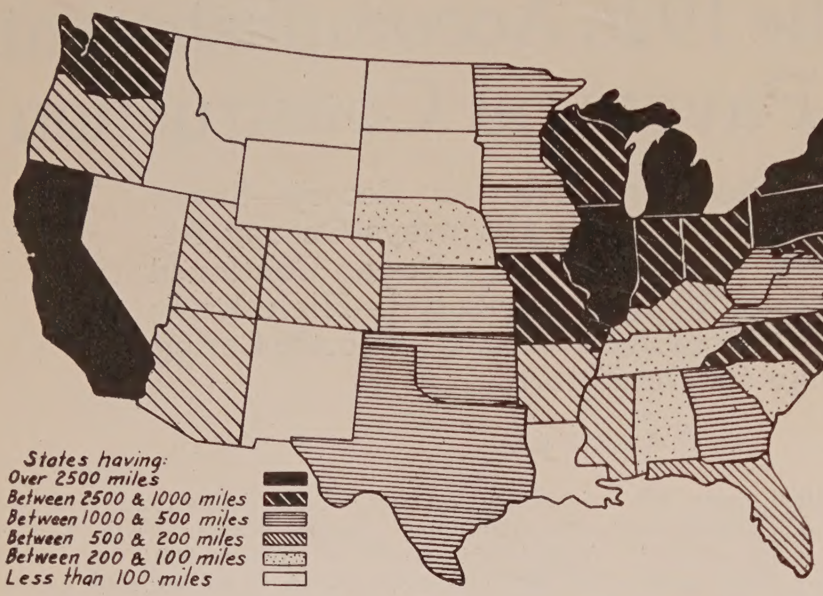
Illinois heads the list with over 12,000,000 square yards of concrete pavement awarded during 1926. In five other states—California, Indiana, Michigan, New York and Pennsylvania—awards of between 5,000,000 and 10,000,000 square yards were made. In the next class, awards of between 1,000,000 and 5,000,000 square yards, there are 17 states—Florida, Georgia, Iowa, Kansas, Kentucky, Maryland, Minnesota, Missouri, New Jersey, North Carolina, Ohio, Oklahoma, Tennessee, Texas, Virginia, Washington and Wisconsin.

Thirty states increased their 1926 yardages over the 1925 awards. In most of the other states except Illinois, the decrease was very small. Illinois was faced with a peculiar condition which caused the drop from 16,000,000 square yard in 1925 to 12,000,000 in 1926. Because of the fact that work on the new $100,000,000 Illinois bond



issue cannot go ahead until all of the roads designated on the first bond issue were completed, and because right-of-way troubles delayed the completion of these unpaved stretches in the original bond issue section, the state was prohibited from going ahead on its new big highway improvement venture.

For the last four years, the yardage of concrete highway awards has fluctuated between 53,000,000 and 63,000,000 square yards. As one state completes its highway program, the other state begins. The active periods of the various states occur in different years and keep the volume of highway improvement pretty nearly within the limits of the last four years.


States having:
Over 2500 miles ■
Between 2500 & 1000 miles ▨
Between 1000 & 500 miles ▤
Between 500 & 200 miles ▨
Between 200 & 100 miles ░
Less than 100 miles ☐

Map showing distribution of concrete highways by states

Street Pavement Awards

It is in the concrete steel awards that the 1926 gain was attained. It is significant that much of this increase was due to greater use of concrete for paving the streets in big cities. In the big city field, Los Angeles leads with 1926 awards of about 2,500,000 square yards and a total yardage of more than 10,000,000. Other large cities with outstanding volumes of concrete pavement awards are: Seattle, Kansas City, Atlanta and Chicago. Chicago began placing concrete paving on a large scale during 1925 and during both that year and 1926, Chicago's paving program selected concrete for more than half of the total yardage placed.

Construction Features

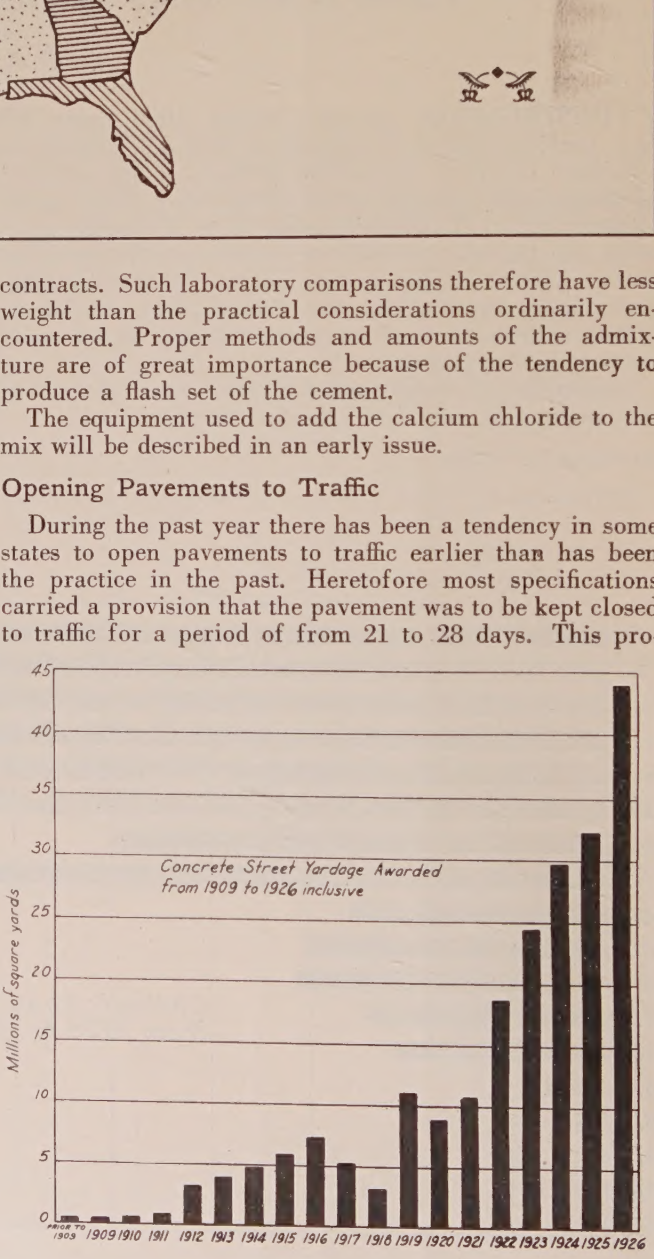
The past year has seen an important development in the studies and experiments in the use of high early strength for concrete pavements. This was probably the most outstanding development of the year. The other construction features, such as concealed longitudinal joints, more accurate methods of proportioning aggregates, the use of designed mixes, greater care in finishing, etc., were developments that were begun during the last two years. The past year did see these features used to a greater extent and they have now passed the experimental stage and may be considered as standard practice in most of the progressive road and street building communities.

Some states have adopted the use of calcium chloride as an admixture for curing the slab. In one state 14 out of 15 contracts awarded on the 180 miles of concrete pavement constructed, have used this method of curing with very favorable results. It is considered a more convenient method of curing and in many cases is less expensive. While there is some doubt as to the effectiveness of calcium chloride as an admixture for curing when compared with water-curing under laboratory methods, it is common knowledge that conditions maintained at the laboratory are seldom secured in actual practice on paving contracts. Such laboratory comparisons therefore have less weight than the practical considerations ordinarily encountered. Proper methods and amounts of the admixture are of great importance because of the tendency to produce a flash set of the cement.

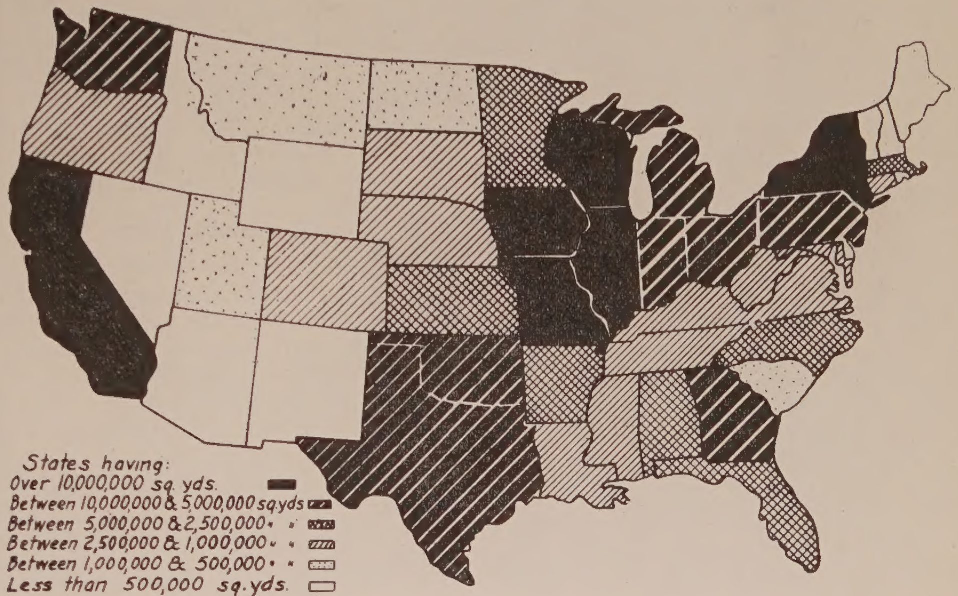
The equipment used to add the calcium chloride to the mix will be described in an early issue.

Opening Pavements to Traffic

During the past year there has been a tendency in some states to open pavements to traffic earlier than has been the practice in the past. Heretofore most specifications carried a provision that the pavement was to be kept closed to traffic for a period of from 21 to 28 days. This pro-


Concrete Street Yardage Awarded from 1909 to 1926 inclusive

vision has worked hardship on the contractor as well as on the traveling public. Several states have therefore adopted the policy of opening the pavement to traffic when tests showed the concrete to have hardened sufficiently to carry the load. In these days of the design and control of concrete, it is possible to regulate the speed with which concrete will gain strength and a saving in the time of opening pavements to traffic will effect decided economies.


States having:
Over 10,000,000 sq. yds.
Between 10,000,000 & 5,000,000 sq.yds
Between 5,000,000 & 2,500,000 " "
Between 2,500,000 & 1,000,000 " "
Between 1,000,000 & 500,000 " "
Less than 500,000 sq.yds.

Map showing distribution of concrete streets by states

The practice adopted by some of the states is to open the pavement as soon as the test beams show a modulus of rupture around 350 pounds. Beams for making these tests are cast each day from the regular run of the concrete and subjected to the same curing conditions as the slab itself. The use of this method has resulted in opening some pavements in a week or ten days instead of the usual three or four weeks. This subject also will be discussed in greater detail in an early issue.

High Early Strength Concrete

Many state highway departments and municipalities have experimented during the past year in the placing of concrete, designed to attain higher early strength than is commonly the case. This development has provided a way out from one of the most serious objections brought against the use of concrete for pavement construction, namely, the length of time required for curing.

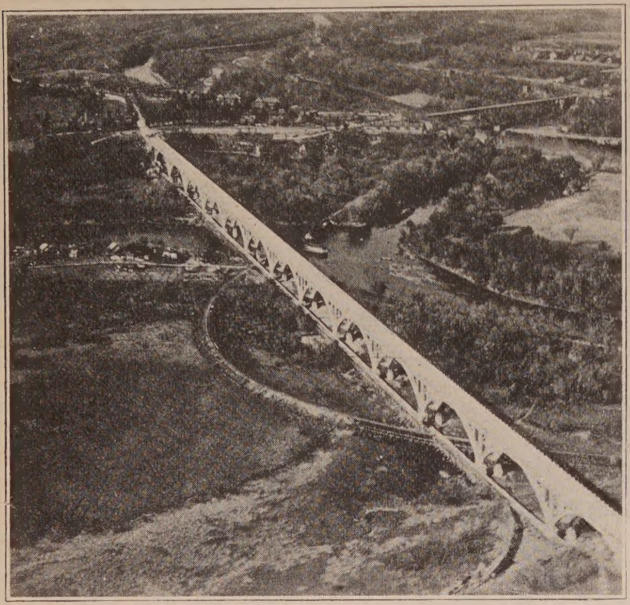
With the possibility of opening pavements in from three days to a week, that objection is removed and concrete has been made available for use on our busiest city streets. How one municipality used the methods to attain high early strength concrete, is described in this issue.

The use of this type of concrete is also gaining favor for highway and street repairs. One state has opened patched sections to traffic eight hours after the completion of the concrete patch. They used a $1:1\frac{1}{2}:2\frac{1}{2}$ mix with a 2 per cent solution of calcium chloride and in-

Wider Woodward Avenue in Oakland County, Mich., just north of Detroit, a super-highway having two 44-foot traffic lanes creased the time of mixing to 5 minutes. The patches were placed in the forenoon, the roadway was barred to traffic during the afternoon and the barricades removed in the evening. No failures have resulted in concrete patches thus installed during the past year.

Design Features

As in the construction developments of the last two years, the design of concrete pavements during the last year has followed the tendencies previously established. The thickened edge type of pavement remains the standard for practically all states and only minor changes have been made in the design details for some states.



The Mendota Bridge between Mendota and Ft. Snelling, Minn., opened to traffic in 1926. This is the longest concrete bridge in the world

In practically every state there are movements on foot for widening existing highways near the larger cities. It is generally accepted as necessary to plan all future highways for wider surfaces than are now being used. Near several large cities the "super-highway" movement is gaining ground and plans are either being made or construction has been undertaken toward this end. Wider Woodward Avenue, near Detroit, is now practically completed and is an object lesson in the wisdom of preparing for future traffic. But the need for wider highways on main trunk lines between centers of population is meeting with responses in the form of widening programs, also. The movement is not confined to roadways immediately adjacent to centers of population.

1927 Prospects

From all indications, highway work and street improvement programs will continue into 1927 with about the same volume as in 1926. Much work is projected and highway sentiment is being crystallized in some of the backward communities.

This year will in all probability see a further development in the movement started in 1926 to open pavements to traffic earlier. There is still a vast chance for improved construction methods on many pavement jobs and the development toward more careful aggregate proportioning, better finishing methods and closer control of concrete quality will undoubtedly be extended to a greater number of projects.

Road Builders Announce Advance Program

At the coming twenty-fourth annual convention and road show of the American Road Builders Association, January 10 to 14, in Chicago, the first day has been set aside as Governors' Day, the second as Pan-American Day, and the third as States Day. An outstanding feature of the convention will be the special exhibits in the foyer of the Palmer House hotel. These exhibits will be made by the American Association of State Highway Officials, Bureau of Public Roads, Highway Research Board, U. S. Department of Commerce, with about a dozen states, Alaska and Canada, and several Pan-American countries contributing.

Double sessions, widely approved last year, will be held again. The Engineering Sessions will be carried on in the Grand Ball Room of the Palmer House and the Constructors' Sessions in the Red Lacquer Room.

Governors' Day

Advance announcements state that on Governors' Day, Tuesday, January 11, following an address by the president, at the general sessions at 10 A. M. in the Grand Ball Room of the Palmer House, Len Small, governor of Illinois, and William E. Dever, mayor of Chicago, will address the meeting. Thomas H. MacDonald, chief, U. S. Bureau of Public Roads, will also speak.

Work preliminary to construction will be the subject of discussion at the Engineers' sessions at 2 P. M. Tuesday, George F. Schlesinger presiding. At the constructors' sessions at the same hour contracting as a business will be discussed by the speakers, among whom is J. H. Ellison, president of the Associated General Contractors of America. H. A. Wheeler, vice-president of the Union Trust Company, Chicago, and former president of the United States Chamber of Commerce, will talk on "Profit in Industry."

The general session on Wednesday, January 12, promises to be an extraordinarily interesting session, with an international flavor. Diaz Leal of Mexico and R. Keith Compton, director of the Department of Public Works, Richmond, Virginia, will be the presiding officers.

In addition to the general sessions, engineers' and constructors' sessions will again be held separately in the afternoon, on Wednesday. The general subject among the engineers will be construction, while the constructors will discuss practical operating methods.

These sessions will be followed by the business meeting at 4:30 P. M. and the road builders' annual banquet in the Grand Ball Room of the Palmer House at 7 P. M.

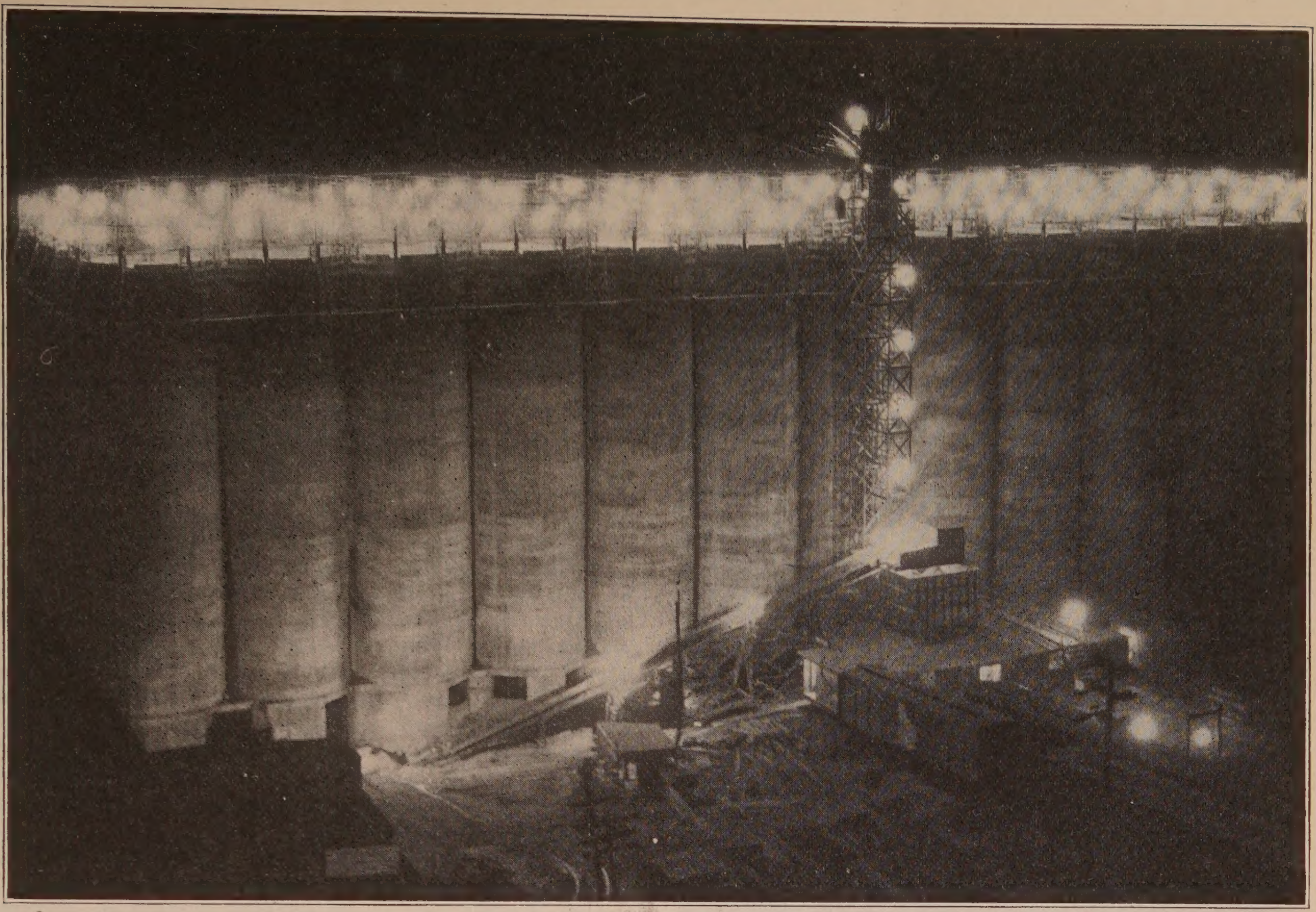
Operation and maintenance is to be the topic of the day at the engineers' sessions on Thursday morning, January 13, at 10 A. M. Theo. J. Wasser of Jersey City, N. J., will preside.

The final general sessions will be held Thursday afternoon at 2, with Dr. Fons A. Hathaway presiding. Four speakers, including J. E. Ellison, Arthur W. Brandt, Frank T. Sheets and J. L. Harrison, are announced in the advance program.

The Highwayman, containing a list of the daily events and the convention program, will be published each day of the convention.

Ohioans to Meet in Columbus

The Ohio Concrete Products Association meeting will be held January 25, 26, and 27, inclusive, at the Neil House in Columbus, Ohio, according to George M. Friel, secretary-treasurer.



The night shift on the job. Four hundred 75-watt lamps were strung around the job to furnish light for the night gang.

Mammoth Concrete Storage Tanks Built With Slip Forms

A Description of the Methods Used in Building 48 Large Concrete Storage Tanks for the Quaker Oats Company at Cedar Rapids, Iowa—Caissons Placed for Foundations — Plant Layout — Slip Form Operation Described — Special Features

By J. M. SKINNER

ONE of the largest building projects of its kind in the United States and one very interesting from a construction standpoint is the erection of 48 mammoth concrete storage bins with a total capacity of 2,000,000 bushels of grain, and an accompanying work house and unloading dock, as part of the Quaker Oats Company's $5,000,000 expansion of the Cedar Rapids (Iowa) plant. The work is being done by the Leonard Construction Company, Chicago and New York, who do all of the Quaker Oats building.

The circular tanks are 25 feet in diameter, 100 feet high and cover an area 102 by 300 feet. The walls are 7 inches thick, the concrete mix being 1:1½:3 for the bottom 15 feet and 1:2:4 above that level. Reinforcing varies from ¾ in. at 10-inch spacing to ½ in. at 1-foot spacing.

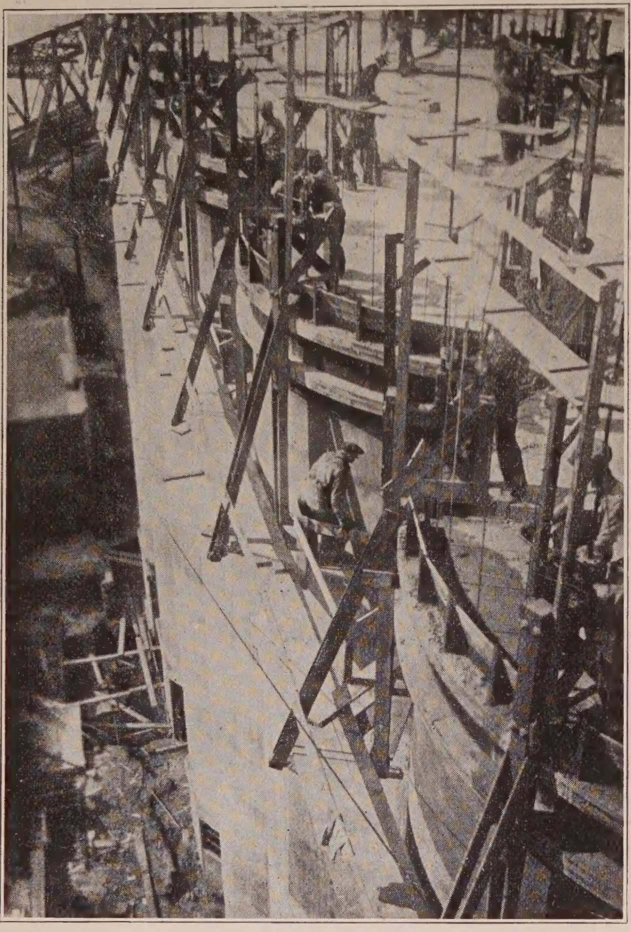
Foundation

The foundation consists of rectangular caissons 15 by 4 feet down into solid rock, which was found at approximately 15 feet below the surface of the ground and 5 feet below the Cedar River, which flows within 25 feet of one end of the elevator.

No great difficulty was encountered from water in digging these caissons except in those nearest the river where concrete placed in cement sacks was necessary to stop the streams of water from entering into the excavation.

Slip Forms Used

Movable forms were used for the bin walls and were made to live up to their name by being raised continuously for 19 days, the time required to pour all of the tanks to a point 98 feet above their bottom slab. During this time 7,500 cubic yards of concrete were poured requiring 50 car loads of cement, 193 cars of rock and 96 cars of sand. We believe that this time is a record for work of this type and magnitude.



An overhead view, showing decking, supporting yokes, jack rods and hanging scaffold of the slip forms.

The forms were made 4 feet high of tongue and groove staves which had previously been soaked in oil to present a smooth and tight surface that would not adhere to the concrete and cause it to rise with the forms. The decking placed over each tank formed a runway for the concrete buggies as well as the bottom form for the slab which is to be poured over the top of the bins. This deck was fastened rigidly to the inner form for the bin walls and of course was raised with the wall forms.

The forms for each tank were built in separate units and with a slide joint between them so that when one unit was being raised it would not lift the others adjoining and thus warp the forms.

By keeping the flooring level, the side walls were kept perpendicular and so the tanks were erected plumb and true. The instrument was set up between shifts and level marks filed on the jack rods, which did not raise, and from these marks the floor grade could be gauged.

Eight jacks per tank were used to raise the forms. These jacks worked on 1-inch rods which relieved the green concrete from the weight of the forms and transmitted it down to the bin bottom slab which supported them. Rods of 16 feet in length were used, one being placed on top of the other as the jacks reached their tops. Two gangs of men on each shift were used to raise the forms, each working from one end to the middle, jacking 1 inch at a time and repeating on the next round.

The work was carried on in two shifts of 8 and 9 hours with jackers working between shifts to keep the concrete from freezing to the forms when the weather caused it to set up rapidly. Four hundred 75-watt lamps were strung around to furnish light for the night gang.

Plant Layout

At the left front of the structure a hopper into which the trucks dumped the stone, or sand as the case may be, was located. Here the materials were fed onto a belt moving up an incline to the large storage bins directly over the mixing hopper. Gravity was used instead of labor to drop the material from the bins into the measuring hopper and again into the mixer below.

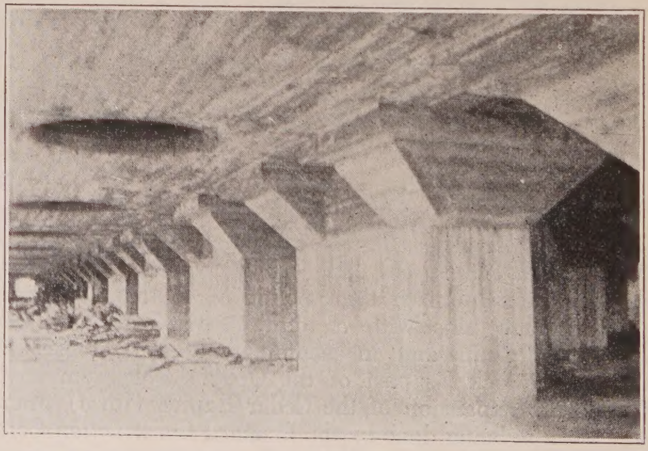
At the right of the structure were the tracks on which the cars of cement are delivered to the shed where it could be unloaded and taken directly to the mixer, thus eliminating the cost of additional handling. The mixer of course placed the concrete into the hoist which raised it to the top hopper where it was spouted into the floor hopper from which the buggies were filled.

A scaffold was hung from the slip form yokes for the use of the cement finishers who trowelled the face of the tanks to a smooth finish while it was still workable in order to eliminate as much porosity as possible. The elements will cause considerable trouble with a rough, porous surface.

The "Workhouse," a rectangular monolithic concrete structure 16 by 64 ft. at the east end of the elevator, was raised with the bins, the floor beams and walls being poured with the movable forms. Key ways with soft steel dowels bent into them lengthwise were anchored into the fresh concrete, so that they would not pull up with the forms, at the correct grade for the floors which were to be poured later. It was necessary to use soft steel dowels so that they could be straightened out into the slab since the majority of hard steel rods will break on the second bending.

Unusual Problems

Mr. Wolflin, a very resourceful man of long experience in construction projects, superintendent for Leonard Construction Company, devised some ingenious methods to meet some of the unusual conditions which were peculiar to this job.



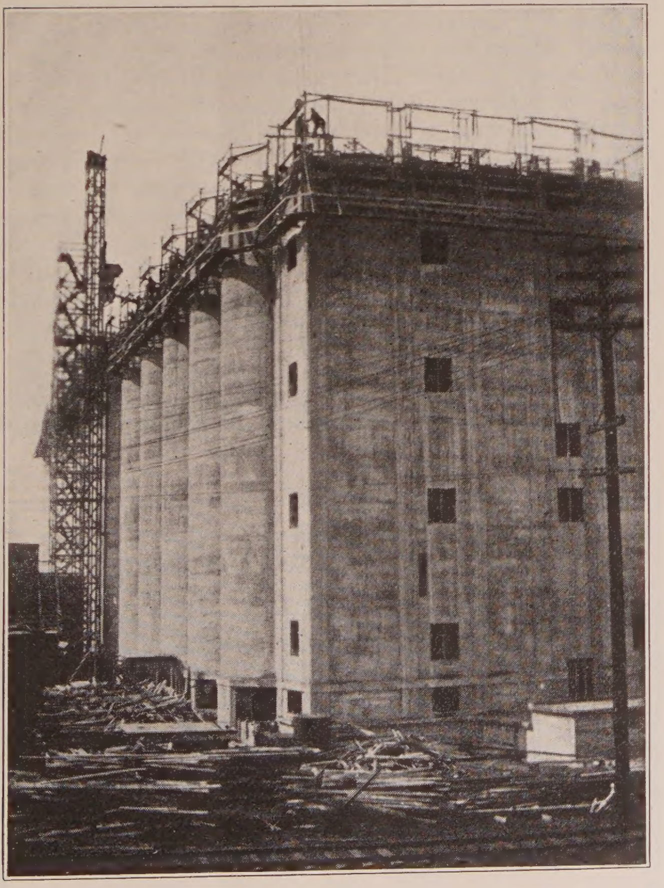
Showing the foundation construction and the basement. Bin bottom slabs are 14 inches thick.

For example, in two of the tanks, 75 feet from the bottom, openings approximately 15 feet wide by 7 feet high with a wall dividing the tanks in two parts, starting up from the top of the openings, were called for. Of course columns were to be placed at the ends of the walls in the openings, but what column of green concrete would support the great weight of a wall 25 feet long and some 20 feet high? To make it more interesting, two jack rods came in each opening and it had already been found that these rods would buckle if the concrete was not poured around them within two feet of the bottom of the supporting yokes. The openings were 7 feet high.

The problem was solved by leaving pockets in the bin walls directly below the ends of the dividing wall to be poured and at a distance far enough below to allow a heavy timber truss to be constructed as the forms moved upward. Shores were then placed on top of this truss to bring the wall bottom form to the correct elevation.

During the early construction of the wall forms this dividing wall form had been built in place, but the ends blocked. As the forms reached the fixed wall bottom form, the blocks were removed from the dividing wall and the concrete allowed to enter.

In the meantime the bin wall forms had been blocked at the sides of the opening when that elevation was reached and a "gallows" constructed to remove the weight from the jack rods within the opening. The "gallows" was constructed by placing two 6 by 6 timbers upright on steel plates for bearing on the concrete already poured. These timbers were long enough to reach well above the top of the moving forms when they would be at the top of the openings. On top of the uprights a timber beam was placed through which two threaded rods, one at each end, were hung by a nut at the upper end. The lower ends were run through another timber beam under the yokes on the two jack rods which were feared would buckle. As the nuts at the top were screwed, the beams under yokes were raised and the weight removed from the jack rods.

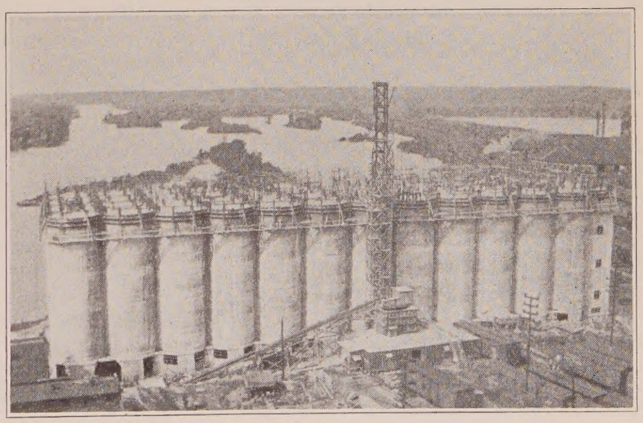


The workhouse, a rectangular monolithic concrete structure at the east end of the bins, was also constructed with slip forms.

Another view of the slip forms.

When the top of the opening was reached by the movable forms, the jack rods were cut and heavy pipe was placed over them, forming a sleeve over the joint and a good stiffener for the rods. The supporting timbers of the gallows were cut to the right length for shores to support the bottom form for the tank wall as it was resumed above the openings.

The form for the columns under the wall was made of sheet metal placed inside of the sliding wood wall forms and was left in place, to be cut off after the concrete had gained its strength.



A general view of the bins under construction.

Weather Conditions

The weather, while the placing of concrete for the tanks was in progress, was fine for ducks, which was also fine for this work. It rained on almost every shift during the 19 days. The men were furnished with slickers, but the forms were not and as a result were damp most of the time and so were swelled tight and smooth.

The concrete did not set up very fast during the wet cold weather so that five feet in two shifts, 24 hours, was all that could be made in safety. Consequently the finishers were able to work a fine surface on the walls. When it was feared that the concrete would not be sufficiently set up to stand alone by the time the 4 feet of forms would move up from it, extra cement was used in the mix to hasten the setting.

All reports from outsiders who have inspected the concrete on this job claim that these tanks are the smoothest and the best ones they have seen.

When concreting had progressed to a point within two feet of the top slab which covers the tanks the continuous pouring was stopped so that the inner and outer forms could be bolted together and the yokes removed, for of course the slab could not be poured with the yokes running down through it.

Another great saver of time and money, was the boring of these bolt holes when the forms were being built. Corks which could be easily removed were then inserted to stop the holes. This saved the delay and cost of hanging a scaffold over the edge in order to bore these holes 98 feet above the ground.

The "Workhouse" mentioned before, is to be raised 90 feet above the top of the bins. In this building will be housed the elevators to raise the grain from the unloading docks, the machinery for running them, the conveyor belts, and the scales for weighing the grain. This extension will be built with the moving forms also, but later because the forms must be rebuilt before concrete can be placed.

In connection with the elevator and workhouse, an unloading dock is being built. The dock or car dumper building will take care of the unloading of grain from box cars by tipping the car to one side and then rocking it from end to end and thus spilling the grain out of the door. The grain will fall through a grating on to conveyor belts taking it to the workhouse where it will be hoisted to the top of the bins and distributed for storage.

This building is mostly underground. It is of reinforced concrete designed and waterproofed to resist 8 feet of water pressure for it is that far below the high water of the Cedar River.

The waterproofing is taken care of by a membrane, 2-ply felt, well mopped with asphalt, forming a continuous surface over the bottom and sides of the basement and protected by a 6-inch slab and wall of concrete richened with lime.

The building program of the Quaker Oats Company also covers a 13-story package building, 260 by 110; a 3-story 60 by 220 and 2-story 80 by 220 reinforced concrete warehouse; the wrecking of a feed house and erection of a 10-story building in its place. Another battery of 36 storage bins is being considered.

Wisconsin Products Men to Meet February 3-4

The Wisconsin Concrete Products Association, whose meeting last spring was widely heralded as an unqualified success, has selected the time of their next annual convention as February 3 and 4. Every products manufacturer in the state, regardless of present non-membership, and those from other states whose work will permit the journey to Milwaukee, should make it a point to attend. A very worthwhile program has been arranged, according to A. P. (Art) Kuranz, the present secretary.

American Concrete Institute Meeting Plans

The twenty-third annual convention of the American Concrete Institute will be held in Chicago at the new Palmer House on February 22, 23 and 24, and the Concrete Products Association will meet at the same time and place. It is to be expected, then, that sessions will be so arranged that concrete products producers will be able to attend specific sessions of both organizations without any conflict of time.

Program

The subjects of a few of the papers to be presented before the convention include quality control on the Chicago Wacker Drive project, accompanied by motion pictures, the construction of a government pier in the state of Washington, employing quick-hardening cement, and proposed standard building regulations. The Institute Committee, C-4, on forms, will report, in symposium form, on the use of steel forms. Foreign reinforced concrete work will be brought up in a paper to be delivered by Adolph Buhler, chief engineer of bridges of the Swiss National Railways. The paper will treat the design and construction of the Grandfey viaduct, a multiple-arch, double-track railway bridge, recently completed in Switzerland.

Products Features

The Institute program will give two of its eight sessions entirely to products manufacturing problems, this accounting for the entire day on Wednesday, the second day of the convention. The evening period of the same day will be an architectural session. The Thursday morning session will be of particular interest to products men who are at the same time producers of aggregates, and the afternoon and evening sessions of the same day will be interesting to the products man as well as to other concretors. A government representative will disclose some hitherto unconsidered fundamental characteristics of aggregates in a paper at one of these latter sessions, followed by discussions on curb and gutter specifications, crazing, and a resume of current researches. The last two sessions will also consider the water-cement ratio theory in a new way, taking into account the matter of time. Thus the important consideration will be that of the amount of water in the concrete at the time of hardening, and not at the outset. This will be of importance to the products man in his mixing, molding and curing practice, as well as to the concretor on monolithic work.

Social

The Greetings Committee will welcome newcomers, while at an informal dinner Thursday evening there will be one speaker with a subject of general interest.

Sand and Gravel Program Speakers Announced

G. S. Brown, President of the Portland Cement Association, has been scheduled to address the eleventh annual convention of the National Sand and Gravel Association at Cincinnati, Ohio, on January 17, 18, and 19.

Two other speakers of note appearing on the program are Professor Duff Abrams of the Association laboratory, and R. J. Stimson, Chief Engineer of the Pennsylvania Railroad.

High Early Strength Concrete Used for Waukegan, Illinois, Streets

How 3-Day Old Concrete Pavements Having the Strength Ordinarily Attained at 28 Days Were Placed to Facilitate the Movement of Traffic—a Description of the Methods Used

WAUKEGAN, a city of 30,000 people, concrete-paved 14 miles of streets the past season. A street improvement of that magnitude was bound to hinder traffic, especially on through routes traveled daily by hundreds of cars driven by strangers. This difficulty was partly overcome by paving important intersections with a rich concrete that developed in three days the strength expected of ordinary concrete in 28 days. Results were so satisfactory that high early strength concrete was used when the only street leading to the interurban freight depot was paved and also on car track pavement built by the street railway company.

Work Was Carefully Planned

All the construction work was laid out so that traffic would be discommoded as little as possible. During the first of the season the mixer was moved from one locality to another so that a completed street would have time to harden and be opened to traffic before a neighboring street was closed for construction. Much of the work was in outlying districts so that the system worked very well until streets nearer the business district were to be paved. Then four intersections were left, over which practically all the through traffic as well as the hundreds of local cars traveling from north to south in the city had to pass. The city engineer decided that if there was any way to avoid closing these intersections for a long period it would be well worth while. After investigating the possibilities of getting 28-day strengths in three days by the use of a little extra portland cement he determined at least to give the method a thorough trial.

Edison Court, the only street for hauling freight to and from the depot

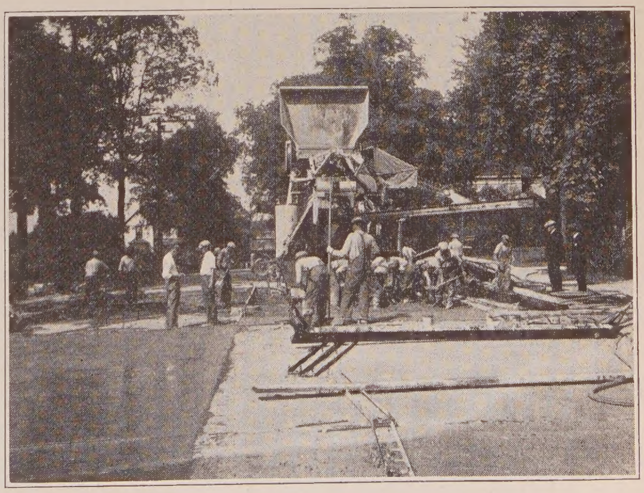
Proportions

The proportions necessary for concrete of the desired three-day strength were determined from the results of previous tests made by the Research Laboratory of the Portland Cement Association. These tests showed that, with normal summer temperatures, a concrete mixture containing a sack of cement for each foot and a half of sand and two and a half feet of stone would have a compressive strength when three days old of about 2,500 pounds per square inch, providing not more than four and a half gallons of water were used for each sack of cement in the batch. This mixture was the one decided upon, and to assure workability and still greater strength the mixing time was changed to two minutes instead of the one minute used with the regular mixture.

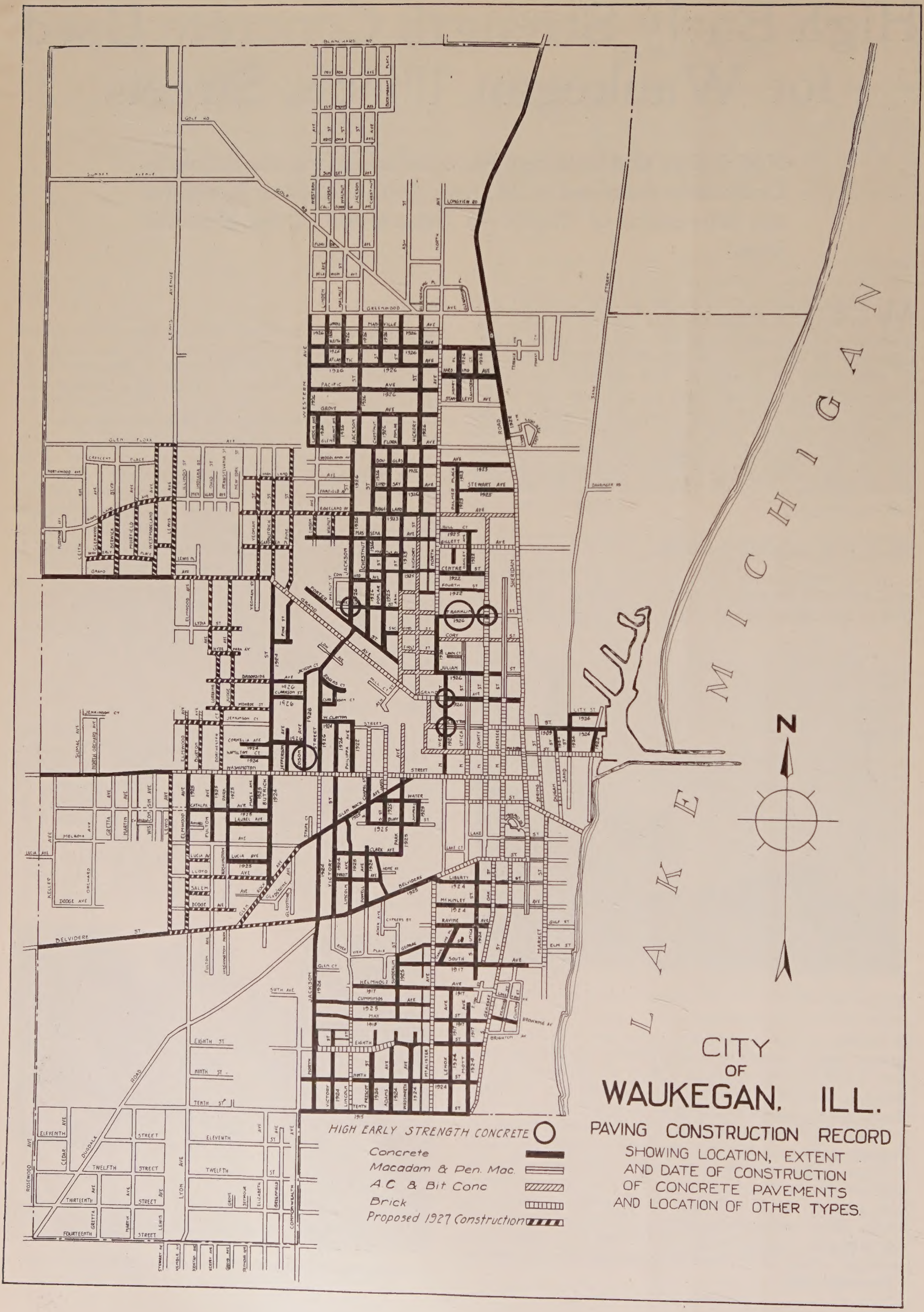
Blaw Knox steel bins with measuring hoppers adjusted for a five-sack 1:2:3½ batch had been in use. No change in measurement was necessary for the new proportions; they were secured by adding two sacks of cement to the regular batch of materials.

Water Content

The quantity of water used per sack of cement was recognized as the fundamental consideration in getting high strength. If the desired concrete were to be obtained the total amount of mixing water, which includes the water in the aggregate as well as that emptied into the mixer drum, could not exceed four and a half gallons per sack. Tests showed that a cubic foot of sand contained a maximum of three-fourths of a gallon of moisture. In a 7-sack 1:1½:2½ batch the allowable mixing water would be 31½ gallons of which 8 gallons was contained in the



A general view of one of the intersections, opened in three days



CITY
OF
WAUKEGAN, ILL.
PAVING CONSTRUCTION RECORD
SHOWING LOCATION, EXTENT
AND DATE OF CONSTRUCTION
OF CONCRETE PAVEMENTS
AND LOCATION OF OTHER TYPES.

sand, leaving 23½ gallons to be added. Adjustment of the water tank to measure the smaller quantity of water was the only change necessary when the mixer reached the intersections. The water-measuring device on the new 21-E Rex paver proved very reliable and the batches showed remarkably uniform consistency. The concrete was neither harsh nor dry and was easily finished with the regular hand methods in use on the rest of the work.

On the regular street work the slabs were cured with calcium chloride, which was spread on the surface, but for the intersections curing was accomplished with burlap strips which were sprinkled constantly. The change in curing methods was made because concrete a few days old, while it may have high strength, is rather easily abraded, when it is damp. If calcium chloride had been used there would have been no chance to let the surface dry before it was opened to traffic, but with burlap curing the sprinkling was stopped and the pavement allowed to dry out for 24 hours before the barricades were removed.

The first intersection built in this manner was finished on Tuesday and opened on Saturday, the others after a three-day curing period. Work was planned so that no two intersections were closed at once. As a test of the efficiency of the new methods 6 by 12-inch cylinders were

Placing the concrete. Note the dry consistency

Edging, and finishing with a long-handled float cast with the high early strength concrete, some to be broken when three days old, some when seven and others at 28 days. The results of these tests were gratifying as greater strengths were developed than had been expected.

Street Railway Work

Satisfaction with high early strength concrete was so great that the Chicago, North Shore and Milwaukee Railway, which operates the street railway system, decided to use it in paving the car track area on Franklin Street. This street carries the double track line connecting part of the city's residential district with the industrial district. If workmen were to get to their jobs bus transportation had to be provided while the street was closed. That meant additional cost which it would be well worth while to reduce by spending a little money for concrete which would develop the necessary strength quickly. As none of the track could be opened until it was all completed it was not necessary to put in the richest concrete for the whole job and proportions ranged from 1:2:3½ to 1:1½:2½ and the concrete developed 28-day compressive strengths ranging from 3,200 to 5,700 pounds per square inch.

The city also decided to use high early strength concrete on one block of Edison Court, the only street over which goods could be hauled from the electric line freight depot. The Edison Court pavement is 40 feet wide and of 7-inch uniform thickness. It is divided into two 20-foot slabs by a longitudinal center joint which made it easy to build it half-at-a-time. The same proportions and quantity of mixing water were used as for the intersections but concrete for the east half of the street was only mixed 1½ minutes while that for the west half was mixed two minutes. The west half was poured on Thursday and the east half on Friday. Both were opened to traffic on the following Wednesday.

On Thursday a gas leak was discovered under the concrete laid the previous day and the pavement had to be opened so that the gas main could be repaired. It required an air hammer to break the concrete which, later tests showed, had a strength of 2,600 pounds per square inch when three days old.

Placing high-strength concrete in track zone

Test Results

Expansion joints were put in at 30-foot intervals and a test cylinder was made from the concrete between each pair of joints, making 14 cylinders for the block. The results of the different sets of cylinders are given in an accompanying table. Note the higher early strengths for pavement cured during the warm days and nights of August as compared with that of Edison Court, which was laid in October. The cylinders were cured on the job, receiving the same treatment as the pavement.

RESULTS OF CYLINDER TESTS

Sample Taken from	Date Made	Average Temp. F.	Age at Test	Av.Cr'shing Load Lbs. Per Sq. In.
Intersection of Clayton	8/16	76	3 Days	3,090
and West Streets	8/17	69	7 Days	4,370
Intersection of Grand	8/26	74	4 Days	3,220
and West Streets	8/26	74	7 Days	3,415
West half Edison Court	10/7	50	4 Days	2,690
East half Edison Court	10/8	58	4 Days	1,910

In any paving program there are important intersections which could well be paved with concrete that can be opened in three or four days. These could be skipped in the regular construction work and left so that vehicles could use the sub-grade while the street on either side was hardening. Then, three or four days before the balance of the pavement was ready for traffic, the intersection could be concreted with the richer mixture and all the street opened at the same time. Even on country roads there are farm and road crossings for which high early strength concrete would be well worth while. And in business districts the cost of the small amount of additional cement and the extra mixing time might be a small item compared with the inconvenience and loss of business which would result from the usual 14-day curing period.

EDITORIALS

Another Milestone

"THE building material of the future will be concrete," wrote Elbert Hubbard a little over 12 years ago in opening one of those pages of reflection and prophecy that characterized his "Philistine" in the days before he sailed on the last voyage of the Lusitania.

The prophecy was made in the face of the first decline that the cement industry had sustained for many years. The market seemed to be amply supplied and prices were low. And yet how far we have gone since then in the fulfillment of that prophecy! During the year just closed the concrete industry used nearly twice the amount of cement that it did in 1915. It is not likely that even the optimistic Hubbard would have ventured to predict so rapid an approach to the predicted goal.

But the goal itself is a long way from being reached. Concrete construction is far from universal —in many communities it is not even accepted at its proper value. Virgin fields of opportunity await the men with vision enough and ability enough to carry the message of permanent and firesafe construction to the thousands—yes, millions—who still accept lightly built and inflammable structures as desirable, or at least unavoidable.

Concrete is the building material of the future. The progress of the last ten years leads us to accept this statement without misgiving. Will the next ten years carry us as far?

The answer depends not so much upon chance as upon the energy and vision of the men now engaged in the concrete industry.

Winter Construction Wins

PROOF of the practicality of winter construction and of its general acceptance is found in the building construction statistics for November. For the first time in the construction industry, the winter months showed an increase in construction activities. The volume of construction work under way in November very nearly reached the level of mid-summer activities.

The persistent efforts of far-sighted individuals and organizations in trying to wipe out the inefficiencies of short construction seasons are beginning to bear fruit. To the concerted work of these engineers, material men, equipment manufacturers and progressive contractors in telling the story of the advantages of year-round construction belongs the credit for this important step forward in the construction industry.

Early Use of Pavements

THE development during the past year of methods of concrete pavement construction that will permit their earlier use by traffic has been, perhaps, the greatest step forward in concrete pavement construction practice during the past year.

All concrete does not gain strength at the same rate. By observing some of the fundamental principles of making good concrete, it is possible to build concrete pavements that attain strengths in less than a week equal to the strengths ordinarily attained only after a much longer period of time has elapsed. The methods of the concrete pavement construction used in Waukegan, described in this issue, illustrate this progressive step.

In the past, engineers have specified an arbitrary length of time for curing pavements before traffic was permitted to use them, even though it was possible to govern the rate at which concrete developed strength. The new tendency to determine (by one of several methods) the strength of the concrete and to open the pavement as soon as a required strength is obtained, opens up new possibilities to extend the popularity of concrete pavements.

Even though high early strength concrete is slightly greater in cost, this increase is more than offset by the economies following the early use of the improvement.

Inventory Time

NOW is a good time for the products manufacturer to lock himself in his office and take stock of his experiences during the past year.

A careful study of his books for the year will show many things if he has kept them honestly. An analysis of his cash, stock, equipment and plant, if properly made, will show him if he has lost or made money during the year.

It is not enough to say that he did so many thousands of dollars of business—that block sold for so much and cost so much to manufacture.

The block plant that merely paid its owner a salary did not earn money. If it did not earn a fair return on the investment as well as paying its active officers a salary, it did not show a profit.

Also the machinery may have depreciated to such an extent that it will require considerable repair or even replacement early next year. The plant may need a new roof or any number of similar needs for expenditure may arise.

Unless all these expenditures are written off and provided for in the computation, the products manufacturer cannot say with accuracy that he has made money during 1925.

How Precast Curb Are Made in Holland

The Manufacture of Precast Concrete Curb Not Confined to America—One of the Largest Products Plants in Holland Makes a Great Quantity—the Dutch Methods of Production

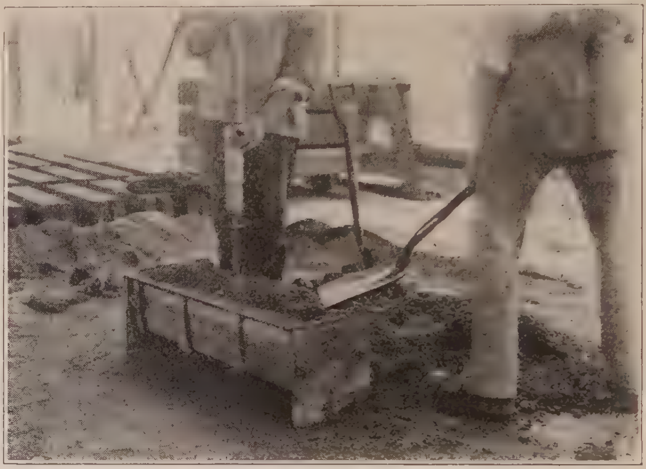
By R. E. GELINK
De Meteoor Works, De Steeg, Holland

CONCRETE curb, of the precast variety, is extensively made in Holland. It is produced by one of the most important products plants in that country, the Meteoor Works, at De Steeg. Our concern not only makes precast curb, but produces a complete line of concrete pipe and other products. Since this is an established enterprise and represents a large capital investment, perhaps the products manufacturer in America will find some interesting things in the plant itself. The Meteoor Works began the manufacture of concrete curb prior to 1917. This part of the business has been very successful, since constant attention to the needs of the field, close laboratory control of the product, and an efficient plant permitted the production of a plentiful supply of reliable units that could be sold at a price to compete with the old stone curb hitherto used, and made possible the delivery of required quantities of the units as needed on the job.

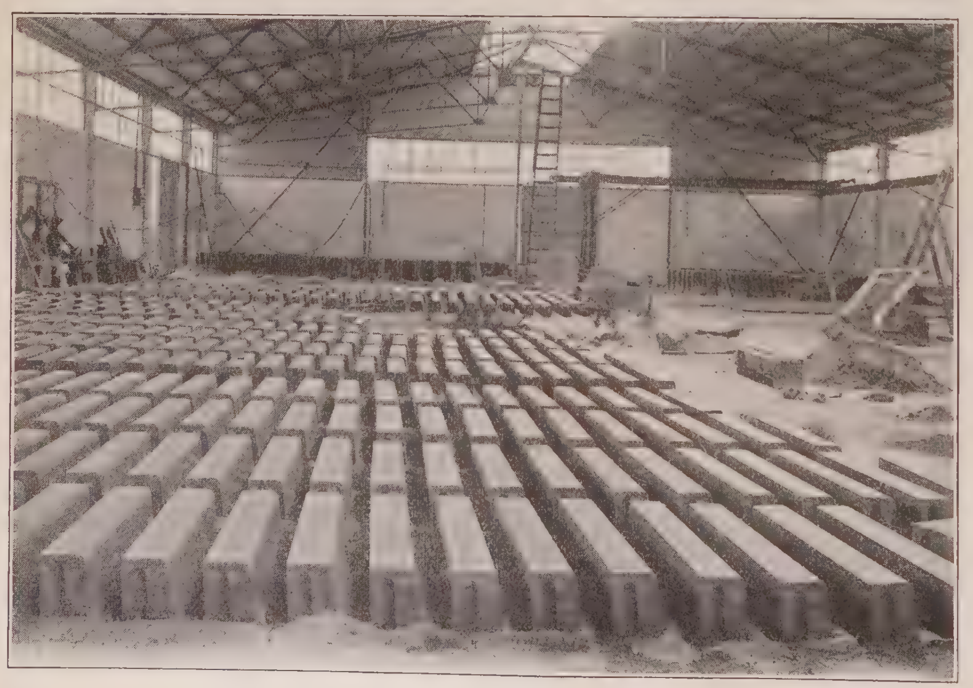
The aggregates for the standard unit are composed of river gravel (graded under 20 mm) and fine sand. No more water is used than is absolutely needed for the hydration of the cement and for the minimum requirements of the tamping process. Tests have shown that the water content used differs but little from that required to give concrete of the maximum strength for that mix. The aggregates and cement are first mixed dry, then the water is added and further mixing is done. A special mix is used for the outer wearing surface of the curb, ordinarily of selected aggregates, and often steel-concrete or a porphyry aggregate is utilized. The latter aggregate is imported from Belgium. Especial attention is paid to obtaining a good hard surface and one that is of the exact contour.

Tamped with Air Tool

The curbs are tamped in iron molds resting on the floor, and the tamping is accomplished by means of a



Ramming the concrete in the mold, which is stripped as soon as the operation is completed. This is a face-down process.



A view inside the plant, with a stock of units curing on the sand bed, and the mold at the right pneumatic tamper of the type manufactured by the Chicago Pneumatic Tool Company, of New York City. The molds form the curb units top downward, and as soon as the tamping is completed the unit is laid on a bed of sand in its normal position, and the mold is removed.

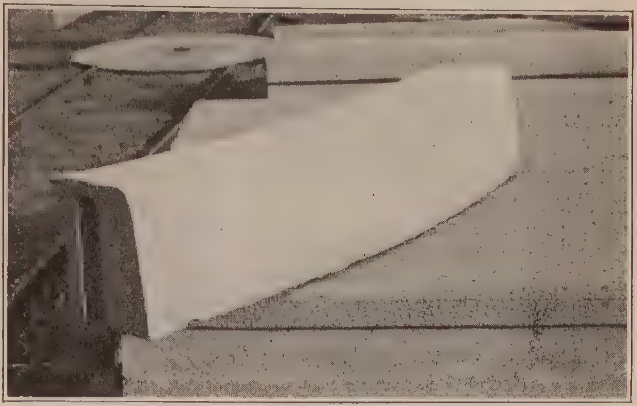
The units remain on this sand bed for a period of two to five days, depending upon the outside temperature, and during this period they are kept wet. They are then removed to the yard, where they are allowed to cure for another two to six weeks, after which they may be shipped to the job. In the winter time all work is done inside the plant, while in the summer the seasonal demand is met by manufacturing units in the yard as well as in the plant.

Here are some straight and curved sections in service in a Dutch city.

Special Facings

The selection of material for the wearing surface of the curbs depends upon the severity of the service that the units must withstand. We once tried the use of steel strips imbedded in the surface, but that did not give entire satisfaction. Now the special cases are met by the use of the steel-concrete invented by Dr. Ing. A. Kleinlogel, of Darmstadt, Germany. This material consists of a mixture of steel grains and cement. The steel grains, which are sharp, irregular bits, come in three sizes: coarse, medium, and fine. The three sizes are properly proportioned with the cement to give a concrete that resists considerable wear. The steel-concrete facing is generally made about ten millimeters thick, as this thickness has been found to be ample. It is about twice as hard as granite, yet the cost is about 30 per cent lower than granite.

Ordinarily the curb units are not reinforced, except where they are to be used with a reinforced slab. Since the units are not reinforced they cannot be jointed in the manner used in the United States. Instead, they are made with an interlocking feature, a tongue in one end and a groove in the other, the tongue just fitting the groove.



A straight curb section, showing the face and the groove for the interlocking feature.

Test Results

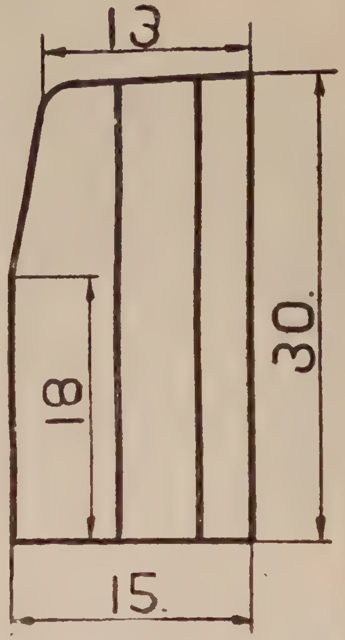
The curb units designed according to the drawing reproduced herewith, known as Model N, with a height of 30 cm. (11.8 in.), a bottom thickness of 15 cm. (5.9 in.), an upper thickness of 13 cm. (5.1 in.), and a length of 100 cm. (39.37 in.), have been tested as a beam, and have shown up quite well. When supported at two points 80

This is part of the stock of curb units in the storage yard. Note the tongue end, which interlocks with the next unit in the curb cm. (31.5 in.) apart and loaded in the middle, the ultimate load attained was found to average 3600 kg. (7936.5 lb.). The compressive strength of the concrete used, when molded in cubes each side of which was 7 cm. (2.75 in.), has been found to run between 300 and 400 kg. per sq. cm. (4,257 lb. per sq. in. to 5,676 lb. per sq. in.).

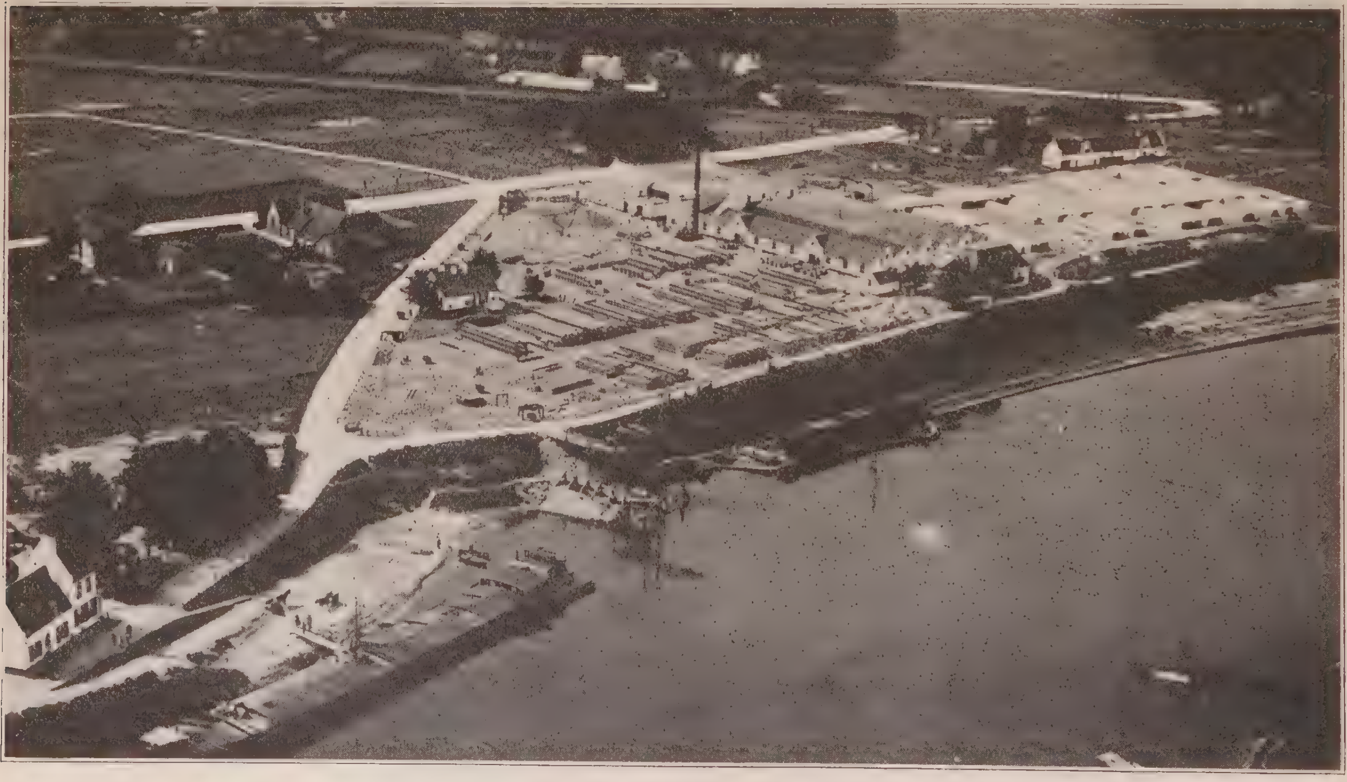
Production Increases Annually

Every year, since production was begun, the turnover has continued to grow. In 1925 the firm delivered over 38,000 meters (124,640 lineal feet) of curbing, while from January 1, 1926, to September 1, the company shipped over 40,000 meters (131,200 ft.), and the demand is continuing to increase. This success has been due to a good product, to a favorable geographical location, to convenient water and rail transportation from the plant to the consuming territories, and to the fact that the market is becoming sold on the fact that precast concrete curbing may be used with real economy. The company is on the alert to extend the uses of this product, and to promote not only the standard curb but the special hard-face units as well.

This curved section takes care of curb returns and the curved streets seen in Holland.



This drawing shows a section through the standard curb, with the dimensions used expressed in centimeters



Aerial view of the curb plant of De Meteoor, at De Steeg, Holland. Note location that gives both rail and water shipments. The materials in the foreground are sewer pipe, drain tile, and so on, while the curb stocks are kept in the yard to the rear of the plant.

Modernizing Two Old Improved Roads

How Two Old Brick Highways in Ohio Were Strengthened and Widened by Resurfacing Them with Concrete to Meet Modern Traffic Demands

ONE of the important problems now confronting highway engineers is the modernizing of old highways that have been improved for the traffic of a quarter of a century ago.

Today's traffic, undreamed of when the old roads were improved, finds these highways inadequate. Increased volume, speed and weight of traffic demands the strengthening and widening of the roads built for the horse and buggy era.

This story describes how two such highways were made suitable for today's traffic.

TWO brick roads in Cuyahoga County, Ohio, were recently smoothed and widened by using them as a base for a new concrete pavement. One road connects Cleveland with the suburban town of Berea; the other, known as the Warrensville or Center road, which carries the local traffic of several suburban villages, is the main route from Cleveland to Akron, and during the racing season is jammed with the patrons of two race tracks.

The old brick road ready to receive its modernizing surface of concrete.

Original Improvement

The Berea road was paved with a 14½-foot brick surface on a macadam base in the period from 1901 to 1904, the Center road was given a 14- to 15-foot brick surface on macadam in 1908. In those early days no one dreamed that roads would ever be required to carry the loads which modern traffic imposes upon them. A two- or three-ton load was all that was expected and the pavements were built accordingly. So long as traffic consisted of horse-drawn vehicles these pavements were entirely satisfactory, but as soon as heavy bus and truck lines were established they began to show distress. The macadam base would not support these heavier vehicles and depressions, which soon became holes, formed in the wheel tracks. As soon as these were patched other holes developed until the cost of maintenance and the annoyance of traveling on such a rough surface made the complete reconstruction of the pavement imperative.

As loads increased in weight vehicles also became larger and more numerous until the 14- or 15-foot widths which were ample a quarter of a century ago are today entirely too narrow. So the problem became one of resurfacing and widening, for which concrete is especially adapted, and after careful consideration by the county commissioners that was the material selected for both roads.

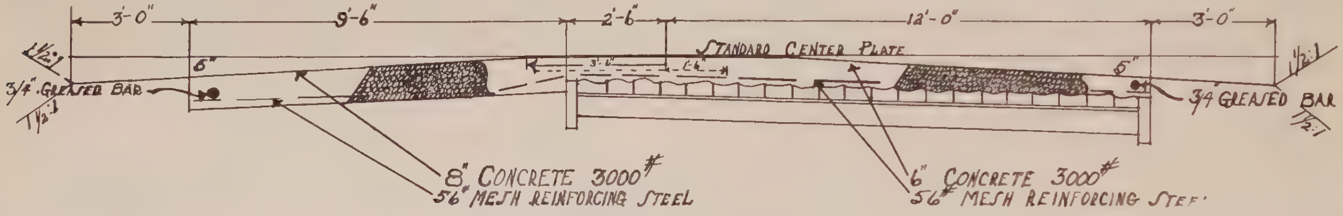
On the Berea road, which carries thousands of vehicles daily, a pavement width of 24 feet was deemed necessary. That required the addition of a 9½-foot concrete shoulder. A width of 18 feet was considered sufficient for the Center road, which required a three-foot shoulder for part of the way and four feet of concrete where the old pavement was only 14 feet wide.

Methods of Resurfacing and Widening

The specifications were the same for both roads. All the widening was done on one side of the old pavement. Where concrete was placed on the brick a depth of at least six inches was specified and for the all-concrete shoulder a depth of eight inches. Whenever more than six inches of slab was required to bring the pavement over the brick to the established grade the extra concrete was to be paid for at a price bid per cubic yard. At first a longitudinal center joint was required but it was so difficult to keep the metal division plate at the proper elevation over the uneven subgrade, and so hard to drive pins to hold it upright, that the center joint was abandoned.

How the old road looked just before improvement started.

Both roads were carefully surveyed so that a grade could be established which would give the necessary six inches of concrete without removing too many brick on the high spots or requiring too much concrete to fill the depressions.



The contract for the Berea road was let to Baldwin Bros. Co., who set up a central proportioning plant at Berea. The plant consisted of a steel Butler bin, with two compartments, one for slag and one for sand, equipped with volumetric measuring boxes. Materials were handled with

Cleaning the old brick before resurfacing.

an Orton and Steinbrenner locomotive crane with 50-foot boom and ¾-yard bucket. Sand was taken directly from cars, but slag, which was shipped in bottom dump cars, was dropped into a concrete-lined pit beneath the tracks from which it was lifted by the crane. This pit helped the crane to get a full bucket for each lift and saved the labor usually expended in cleaning up cars. Materials were hauled to the mixer in four-batch trucks. Sacks of cement were carried on top of the aggregate onto which they were

Showing the reinforcement and the placing of the concrete.

emptied after the truck reached the mixer.

The contract for resurfacing and widening the Center road was let to Nate Siegel, who also hauled in trucks from a central proportioning plant. On this job cement was hauled separately and piled along the shoulder, then dumped directly into the mixer skip.

Construction Methods

On both jobs the forms were set a few inches from the old header-curb on one edge, to allow for small variations in alignment. On the other, the earth shoulder was trimmed to the proper elevation and rolled, just as an ordinary earth sub-grade would be. Any patches on top of the bricks were removed with mattock and shovel and the old pavement was swept clean with wire brooms. Then the inspector stretched a string between the forms at 10-foot intervals and measured the distance from the string to the old pavement at intervals of two feet across the roadway. These recorded measurements were used in figuring the amount of concrete to be paid for by the cubic yard.

A general view of the job, showing the method of delivering pre-proportioned batches to the mixer.

When places were found where the brick were so high that the concrete would be less than six inches thick the brick were removed and the hole thus made was left to be filled with concrete.

Reinforcement

The pavement was reinforced with wire mesh weighing 56 pounds per 100 square feet. This was placed by first depositing a two-inch layer of concrete on the subgrade, then laying the wire mesh, and afterward placing the balance of the concrete on top of it. The lower layer of concrete was raked off with shovels; the top surface was struck-off and belted by a Lakewood screed on the Berea road and an Ord finisher on the Center road. A $\frac{3}{4}$-inch rod, oiled to prevent a bond with the concrete, was placed along each edge to act as a continuous dowel.

Finishing

It was found that concrete which was deposited on the old pavement had to be mixed very dry, else it would be too wet to finish well, for when the subgrade did not absorb water the moisture worked its way to the surface. On the earth shoulder, however, wetter concrete was found necessary. The mixer-man regularly added a little more water to those batches which were to be deposited on the earth.

The pavement was cured for three or four days with strips of burlap laid on the surface and kept wet. Then the burlap was removed and for nine or ten days the slab was sprinkled intermittently. The burlap was carried forward on a four-wheeled platform which ran on the forms.

Strength Was Only Specification

On both jobs the contractor was allowed to determine his own proportions of materials, the only stipulation by the county being that the two 6 by 12-inch cylinders made daily, or cores cut from the pavement, should have a compressive strength of at least 3,000 pounds per square inch when 28 days old. On this contract proportions of about $1:1\frac{1}{2}:3$ were used with not to exceed six gallons of water per sack of cement. The cylinders were tested when seven days old and the probable 28-day strength was figured from the formula:

Spading the concrete along the forms to prevent honeycombing.

$$28\text{-day strength} = 7\text{-day strength} + 30\sqrt{7\text{-day strength}}$$

Finishing the new concrete surface.

Practically all the cylinders developed strengths above those required.

The finished concrete pavements give no hint of the old and uneven surfaces which lie beneath them. They look just like any well-built concrete pavements, ready to carry all of the many heavy vehicles which regularly ply between Cleveland and the nearby towns.

Here and There

Some Random Notes on Visits with Concretors in the Field

PRETTY soon many of the fellows in the field will be shedding their overalls and high boots for a while to come to the conventions to talk things over. Conventions are of a great deal of value. They teach many things. When the other fellow gets down to brass tacks and tells you of his problems and how he solved them, he is apt to tell you just the thing you have been wanting to hear.

And a convention is a fifty-fifty arrangement. After the other fellow has told you how he has improved his business, it is only fair that you tell him of the things you have found helpful.

* * *

PLANT layout is an important factor in products plant operation. We saw a plant that was built on a site that seemed to be made to order. The owner picked it because it permitted the layout he wanted. It was located between the main line of an important railroad and the belt line railroad that connects with all the railroads entering and leaving the city.

All materials are brought to the plant over one of the railways and leave the plant over the other. The materials and the products move from one door to the other without getting into each other's way. Cars coming in with aggregates do not get mixed up on the sidings with cars shipping the finished product. The same arrangement is applicable to a plant receiving and shipping by highway.

* * *

WINTER is a great time to do those many odd jobs that you never find time to do during the summer when every minute of production counts. A thorough annual cleanup and overhauling of the entire plant, yard and equipment is a mighty good thing. It may prevent a breakdown when time is precious. Every piece of machinery functions better and lasts longer if it has periodic attention. There are always little improvements that you thought of when you didn't have time to make them.

And it might be a good thing to give that desk of yours a thorough cleanup, too. You might find the names of a number of prospects that were misplaced when you were in a rush.

* * *

BUSINESS principles are as necessary in the concrete block business as in any other. It requires capital to run a block plant. And there is a period of development in the business before profits are made, just like in any other business. The wise man will see that he is financed to meet this condition before he goes into the business.

One of the biggest block plants in the United States is now running along in great shape. But that plant did not make a single penny for the first two or three years. Other plants in the same city started out at the same time and at various other times, but were not financed to weather this development stage. During the time that plant had been producing concrete block, at least twenty-five other concerns went under because they tried to organize a business on a shoestring.

THE other day a concrete block man spoke of a price-cutting war that was going on in his territory. This fellow represents a concern that has plenty of capital back of it and has always stood for maintaining a fair price for its product.

Then the other block men in the same locality began cutting prices. He tried to get them together to tell them of the folly of this method of getting business but they wouldn't listen. Down went prices another notch.

Another attempt to stop the war was unsuccessful, so this fellow decided to give them a little of their own medicine. He was able to stand the gaff for a longer time than he figured the other fellow could. So *he* started to cut too. Then the fight was on in earnest and it wasn't long before the other block men came to him with the suggestion to "get together on this thing."

Of course, he was willing and what's more he was wise enough not to say, "I told you so."

* * *

THE concrete products business, like all other businesses, requires that a man give it the best he's got if he wants it to go. One plant illustrated this very forcibly.

You could tell immediately when you approached the plant that all was not as well as it might be. The way things were strewn around was evidence enough. The "boss" was located after a lot of trouble—enough to turn any prospective customer away, at least.

"No, business is not so good," he said. "In fact, it is rotten," he continued, growing more specific. "You see, I don't give all my time to this business. I'm interested in languages and that keeps me pretty busy. Now take your name, for instance. It has a Greek root and——."

It seemed a shame to interrupt him. He was so interested in his subject and it was hard to get him back to concrete block.

* * *

ABOUT this time of the year there is a lot of talk about what is going to happen in 1927. Wise men from the East and the West as well as from the North and the South are making a lot of predictions, some of them based on statistics and some of them based on plain "hunches."

One thing is certain—the year 1927 will require a lot of hard work just like 1926 and 1925, etc., all the way along the line. Perhaps even, it will require a little more work than other years if the ledger is going to show a profit at its end.

But this is also true. You have had another year's experience and the lessons learned during the past year ought to show returns during 1927. The kind of a year that you are going to have will depend largely on what you do with it. The market is there and some experts predict that there will be as much building going on this year as there was last. A new year is always a good time to correct past mistakes and sometimes that pays.

The Constitution of Portland Cement Clinker*

Part VII of a Digest on the Literature on This Subject—Studies Based on the Phase Rule of Gibbs—The Phase Diagram and Its Interpretation—The CaO_3, Al_2O_3 and SiO_2 System—Importance of the Other Systems—Rankin's Deductions—The Hydraulic Constituent of Cement Clinker—Studies of Heating and Cooling Curves—Dyckerhoff's Findings—Results of Other Experiments

By R. H. BOGUE

WITH this chapter the review of past studies on the subject of The Constitution of Portland Cement Clinker nears its close.

MUCH material of inestimable value has been reviewed. The studies of the many famous scientists who have contributed their bit to the sum total of the present knowledge on this subject have yielded a wealth of material that has been of the greatest value during the early periods of the industry.

THOUGH many attempts have been made to learn more of the constitution of portland cement, and some writers have maintained that the matter has been adequately determined, the many instances under present day conditions, where the reasoning so far developed has been shown to be incomplete, makes it apparent that a more exact knowledge is necessary for the final solution.

STUDIES of phase equilibria, as presented in this chapter, have helped to eliminate many of the objections raised regarding the results of previous researches. Yet opinion is still divided, in spite of the extensive studies based on Gibbs' rule of phase equilibria.

THIS, the last chapter of the series of articles on The Constitution of Portland Cement Clinker, will be presented in two installments, the first of which will describe the studies and opinions on this subject of phase equilibria, the second presenting the opposition to the phase rule criteria and summing up the modern viewpoint.

Part VII—Phase Equilibria and the Modern Viewpoint

STUDIES on the constitution of portland cement by means of purely analytical processes, proportioning formulas, thermal reactions and the like have yielded information that has been of the greatest value during the early periods of the industry. The process of applying a reasoning by analogy was developed to a state where some have believed there remained little uncertainty regarding the properties of a product which would result from the use of a given set of raw materials, a given proportioning formula, and a given range of burning conditions. The many cases where this reasoning has failed, however, makes it apparent that a more exact knowledge of the several factors involved is necessary to the final solution of this problem.

Such calculations as have been made have been the result largely of plant experience, combined with chemical analysis, which assumed a cement having a given set of properties as more or less the arbitrary standard—the measure of value to which other cements must conform to make them acceptable. No knowledge of the ultimate nature of the product was obtained. If this were to be accepted as the end of research, there could result no growth—no improvement except by fortuitous circumstance.

Many Researches Made

Many attempts have been made to learn more of the constitution of cement. This work has been the inspiration for much interest among investigators and much application of these findings has been made in the industry, both in manufacture and utilization. Unfortunately, however, the experimental bases for many of these studies have been inadequate to unravel the problems of constitution in a system so complicated as that of portland cement. In a great many researches, cement itself has been the material examined. The investigators have failed to realize that, in such a complex system, only a systematic study of each constituent, separately and with each other constituent, could furnish the fundamental basis upon which may be built with assurance the superstructure of cement constitution and behavior. In the work of many who have studied pure compounds, the evidence presented has lacked conviction. Frequently the criteria employed to define the compounds, or their significance in cement, have appeared to be altogether inadequate.

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*Paper No. 3 of the Portland Cement Association Fellowship at the Bureau of Standards.

The Phase Rule of Gibbs

These objections have been eliminated most successfully in the studies which have been undertaken on the basis of the phase rule of Gibbs.[56] Outstanding among these are the investigations conducted at the Geophysical Laboratory of the Carnegie Institution at Washington.[57]

The average composition of portland cement is about as follows:

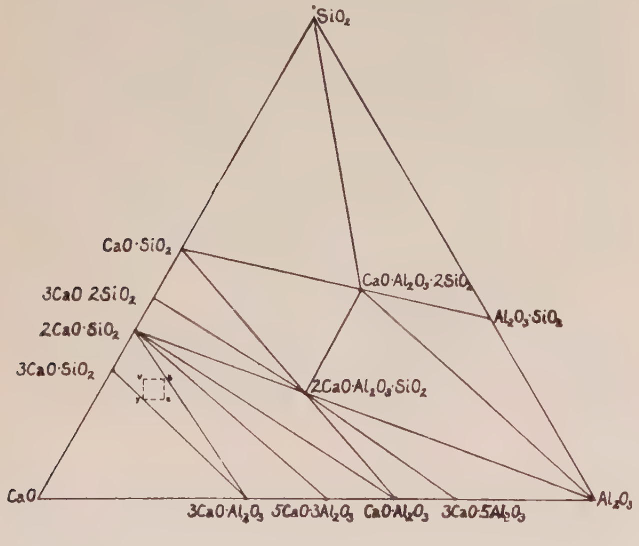
CaO	63.0 per cent	Fe_2O_3	2.5 per cent
Al_2O_3	6.5 "	MgO	2.5 "
SiO_2	21.5 "	SO_3	1.5 "

Although there is some tolerance in composition, the above is probably representative of the material. Several other constituents including alkalies may be present in small amounts. It is apparent that CaO, Al_2O_3 and SiO_2 constitute over 90 per cent of the whole, and the system therefore which would appear to be of greatest significance in determining the compound composition of cement is the $CaO.Al_2O_3.SiO_2$ system.

This complete system has been described by Rankin and Wright.[57] Portland cement is concerned with only a small portion of the system, for nearly all analyses of this material show it to be close in composition to the figures above, and this composition in the $CaO\text{-}Al_2O_3\text{-}SiO_2$ system is found to be well within the field which is composed, at equilibrium, of the compounds $3CaO.SiO_2$, $2CaO.SiO_2$ and $3CaO.Al_2O_3$.

Interpretation of the Phase Diagram

Since it is not always clear to the lay reader just how it may be known that a given grain observed under the microscope possesses a given composition, a brief description of the method will not be out of place.



In the two-component system $CaO.SiO_2$, for example, a considerable number of compositions are made up and heated in a platinum resistance furnace to a given temperature for a period sufficiently long to allow equilibrium to be attained. When this condition is reached the product will contain only two compounds, or if the exact composition of a compound has been used, only this one compound will be present. The melt is quenched by dropping into mercury. The material which was liquid in the furnace will usually be a glass on quenching. The crystalline material remains unchanged. If two crystalline phases are found together at equilibrium, in a given composition, the percentage of the ingredients is changed in succeeding heatings in one direction until, at a rigidly fixed ratio, there is found to be but one phase. The composition is known, so all that remains is to determine accurately the optical properties of the compound. These being determined, the compound may be identified when present in any mixture by noting the optical properties.

By following this procedure for the three two-component systems involved in the ternary system $CaO.Al_2O_3.SiO_2$, all binary compounds, stable under the conditions applied, will be identified. In working with the ternary system, a great many changes representing systematically varying compositions are prepared and examined following similar heat treatments. Rankin reports that in his study of this system about 1000 different compositions and fully 7000 heat treatments and microscopical examinations were necessary. The binary compounds already found are identified when they occur in the ternary system and, where new compounds are observed, it is necessary, for identification, to continue varying the composition until only this one phase is present. The composition of the compound is then given by the composition of the mixture.

In the case of $3CaO.SiO_2$, the compound was not at first observed in the study of the binary system because it dissociates without melting into $CaO + 2CaO.SiO_2$ and does not appear as a primary phase in that system. In the ternary system there is a narrow field of stability for this silicate. $3CaO.Al_2O_3$ is also unstable at its melting point, but dissociates into CaO and liquid.

Manufacturing Conditions

Although, as stated above, the usual mixture of CaO, Al_2O_3 and SiO_2 as found in cement clinker will consist, at equilibrium, of $3CaO.SiO_2$, $2CaO.SiO_2$ and $3CaO.Al_2O_3$, yet in the manufacture of cement it is not always certain that equilibrium will be reached. The temperature may be too low or the period of heating too short. In this case it is to be expected that small amounts of compounds from the adjacent fields will be present. The only other compounds present in the fields adjacent to the one already mentioned are CaO and $5CaO.3Al_2O_3$. These compounds may be expected in underburned clinker and indeed are often found in such material.

These relations are best understood by a study of the ternary diagram, Fig. 1. The pure components, CaO, Al_2O_3 and SiO_2 are represented at the apices of the triangle, the binary compounds by points on the sides of the triangle, and the ternary compounds by points within the triangle. Each point is definitely fixed by its composition, expressed as percentage by weight.

The final product of crystallization of any mixture in a ternary system will consist of three solid phases, except (1) when the composition is exactly that of a ternary compound in which case only the one crystalline phase will be present, or (2) when the composition lies on the line separating two fields in which case there will be two compounds present. Furthermore, definitely bounded areas may be determined in which three definite solid phases may be found always to be present when a liquid within the composition represented by this area is slowly cooled. In Figure 1 the large triangle is divided into a number of small triangles each representing a field in which the three compounds represented at the apices of these triangles occur. On passing from one of these fields to an adjacent field, one compound disappears and a new compound appears.

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[56] Phase Rule, "Scientific Papers of J. Willard Gibbs, New York. *Cf.* Alexander Findlay, "Phase Rule," New York, 1923.

[57] Geophysical Laboratory, "The System $CaO.SiO_2$," A. L. Day, E. S. Shepherd and F. E. Wright, *Am. J. Sci.*, (4) *22* (1906), 265.
"The Binary Systems of Al_2O_3 with SiO_2, CaO and MgO," E. S. Shepherd, G. A. Rankin and F. E. Wright, *Am. J. Sci.*, (4) *28* (1909), 293.
"Preliminary Report on the Ternary System $CaO\text{-}Al_2O_3\text{-}SiO_2$," E. S. Shepherd, G. A. Rankin and F. E. Wright, *J. Ind. Eng. Chem.*, *3* (1911), 211.
"The Ternary System $CaO\text{-}Al_2O_3\text{-}SiO_2$," G. A. Rankin and F. E. Wright, *Am. J. Sci.*, (4) *39* (1915), 1.
"The Constitution of Portland Cement Clinker." G. A. Rankin, *J. Ind. Eng. Chem.*, *7* (1915), 466.
"The Ternary System $MgO\text{-}Al_2O_3\text{-}SiO_2$," G. A. Rankin and H. E. Merwin, *Am. J. Sci.*, *45* (1918), 301.
"The System $Al_2O_3\text{-}SiO_2$," N. L. Bowen and J. W. Greig, *J. Am. Ceramic Soc.*, *7* (1924), 238.
"The System $CaO\text{-}Fe_2O_3$," R. B. Sosman and H. E. Merwin, *J. Wash. Acad. Sci.*, *6* (1916), 532.

The region *v x z y* in the field $3CaO.SiO_2$, $2CaO.SiO_2$, $3CaO.Al_2O_3$ represents the range of compositions for portland cement, exclusive of the minor constituents, according to data on composition from several sources. At equilibrium, therefore, only these three compounds will be present in a cement prepared of the three components CaO (or $CaCO_3$), Al_2O_3 and SiO_2 in the proportion in which they are found in portland cement. And if equilibrium were not attained, as may happen in commercial cement, the adjacent compounds CaO and $5CaO.3Al_2O_3$ would probably be the only additional compounds to be expected. Examination of clinker has borne out the correctness of this view.

Systematic investigations of this type, based on phase equilibria, present data on constitution that are dependent on fundamental criteria. Conclusions are consequently sound insofar as the correct interpretation is placed on the data obtained. The complicated nature of that region of the system in which portland cement occurs has given rise to differences in interpretation, but with more work these differences should entirely be dispelled.

Other Systems Important

It must be emphasized, however that, although the system $CaO.Al_2O_3.SiO_2$ is undoubtedly the most important in portland cement, yet the compounds developed in other systems are very probably of significance. A complete understanding of the constitution and behavior of commercial cement cannot therefore be available until these other systems are worked out. These systems are those which include such components as Fe_2O_3, MgO, alkali oxides, etc. These systems are at present being investigated in the cooperative researches on portland cement being carried out at the Bureau of Standards.

Rankin's Deduction

On the basis of these studies on the system $CaO.Al_2O_3.SiO_2$, Rankin[58] has reduced the probable course of clinker formation somewhat as follows:

In the pure system made up of $CaCO_3$, Al_2O_3 and SiO_2, properly mixed in the correct proportions, the CO_2 is first evolved. Following this, the lime combines with the other components to form $5CaO.3Al_2O_3$ and $2CaO.SiO_2$, since both of these form readily. The $5CaO.3Al_2O_3$ has the lowest melting temperature of any of the compounds formed. At slightly higher temperatures the above compounds unite with more lime to form $3CaO.Al_2O_3$ and $3CaO.SiO_2$. The flux first to appear should be formed at the eutectic temperature for the three compounds $2CaO.SiO_2$, $5CaO.3Al_2O_3$, $3CaO.Al_2O_3$, which is 1335° C. As the temperature rises, the amount of flux increases and the rate of formation of the $3CaO.SiO_2$ and $3CaO.Al_2O_3$ increases proportionately, until the $5CaO.3Al_2O_3$ has entirely disappeared and the formation of the $3CaO.Al_2O_3$ has been completed. There now are present in crystal form in the liquid, $3CaO.SiO_2$, $2CaO.SiO_2$, $3CaO.Al_2O_3$ and CaO. With further rise in temperature the $2CaO.SiO_2$ continues to combine with CaO to form $3CaO.SiO_2$ until eventually the CaO is entirely combined. The amount of $2CaO.SiO_2$ is correspondingly decreasing during this process, and the $3CaO.Al_2O_3$ is going into solution. At about 1455° the solution of the $3CaO.Al_2O_3$ is complete and but little free CaO is left uncombined. Complete melting is not effected until a temperature of about 1900° is reached. But equilibrium is attained without going to the temperature of complete fusion. The rate of attainment of equilibrium, however, will depend on the temperature and on the amount of flux present.

The Lesser Constituents

The lesser constituents such as Fe_2O_3, MgO, etc., probably greatly lower the degree of temperature required for the attainment of equilibrium in a given time period. In a mixture containing CaO, 68.4 per cent, Al_2O_3, 8.0 per cent, and SiO_2, 23.6 per cent, Rankin found that at 1650°, 30 per cent of it was melted and 70 per cent was solid crystalline material. Rankin states that this 30 per cent of liquid constitutes "a proportion of flux which would be sufficient to admit of the necessary reactions going to completion in a reasonable time." The composition of the cooled clinker is then approximately: $3CaO.SiO_2$, 45 per cent; $2CaO.SiO_2$, 35 per cent; and $3CaO.Al_2O_3$, 20 per cent. By the presence of such other constituents as are found in commercial clinker, Rankin found that the temperature of burning which would produce about the same equilibrium conditions was reduced to 1525° for a "white" cement which was relatively free of Fe_2O_3, and to 1425° for a "gray" cement, which was the usual commercial product.

The "Hydraulic Constituent" of Cement Clinker

In 1912, Janecke[59] published a paper on "The Constitution of Portland Cement Clinker" in which he took issue with the investigators of the Geophysical Laboratory.

Janecke found himself unable to accept the existence of $3CaO.SiO_2$ because it had been found only in systems containing alumina. He says,

> The existence of a real binary compound which can be identified only in a ternary system is altogether improbable, especially since it cannot be prepared in the pure condition. The supposed tricalcium silicate is probably the compound $8CaO.Al_2O_3.2SiO_2$, discovered by me.

This compound, Janecke believes to be the alite of Tornebohm, while the remaining compounds are stated to be $2CaO.SiO_2$ (belite), $3CaO.Fe_2O_3$ (probably celite) and small amounts of CaO (probably felite). In rare cases, with compositions very poor in lime, he suggests the probable occurrence of a second lime-poor ternary compound, $CaO.Al_2O_3.2SiO_2$, or perhaps $3CaO.Al_2O_3.2SiO_2$. Janecke expresses the average composition of clinker as follows:

	Per Cent
$8CaO.Al_2O_3.SiO_2$	47.15
$2CaO.SiO_2$	39.7
$3CaO.Fe_2O_3$	5.75
CaO	7.4

The evidence upon which Janecke bases his contention for the existence of $8CaO.Al_2O_3.2SiO_2$ seems to have been obtained partly from a theoretical consideration of the failure to obtain $3CaO.SiO_2$ except in the presence of Al_2O_3, and partly from experimental data on cooling curves. Janecke found a sharp break to occur in the cooling curves of this ternary composition at a temperature of 1382°, and in his first paper reported that it melted congruently, that is, the compound melted completely into a liquid of the same composition. Concerning this definite solidification point, Janecke says:

> Such a point can occur only for compounds or for eutectic mixtures. The latter can be ruled out since

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[58] G. A. Rankin, "The Constituents of Portland Cement Clinker," *J. Ind. Eng. Chem.*, *7* (1915), 466.

[59] E. Janecke, *Z. anorg. Chem.*, *73* (1912), 200.

> mixtures adjacent to $8CaO.Al_2O_3.2SiO_2$ solidify at lower temperatures. . . . This uniform solidification is not in agreement with the diagram of Shepherd and Rankin, according to which $8CaO.Al_2O_3.2SiO_2$ is a mixture. On cooling the melt, these authors claim, first, a separation of CaO through a definite time interval, a lengthening of which causes precipitation of the other compounds, and the resolution of the lime. A solidification of this sort could never produce a cooling curve even approximating the one obtained.

These arguments were at once answered by Rankin and Wright.[60] They point out that the $3CaO.SiO_2$ does occur in the binary system, although not as a primary phase in that system.

Breaks in Heating Curves

Further experiments were performed on a mixture of the composition $8CaO + Al_2O_3 + 2SiO_2$ by observing both heating and cooling curves from 1200° to 1600°. The heating curves showed two breaks; one at 1404°, the other at 1454°. On the cooling curve, one break only was found at a temperature of about 1370°.

The reasons for these breaks were established by making a series of quenches of the same composition. In these experiments, the phases present were as follows:

Temperature	Phases Present
1391°	$3CaO.SiO_2$, $2CaO.SiO_2$, $3CaO.Al_2O_3$.
1432°	$3CaO.SiO_2$, $2CaO.SiO_2$, glass.
1475°	$3CaO.SiO_2$, glass.

It appears, according to Rankin and Wright, that the break in the heating curve at 1404° represents the temperature of the quintuple point for $3CaO.SiO_2$, $2CaO.SiO_2$ and $3CaO.Al_2O_3$, at which point the $3CaO.Al_2O_3$ goes into the liquid phase. Also, that at some temperature between 1432° and 1475° a break should result due to the solution of the $2CaO.SiO_2$.

The cooling curve shows only one break which was far below the temperature of the quintuple point because of undercooling, which is common in silicate charges.

From these experiments it would appear that Janecke's compound was a mixture of $3CaO.SiO_2$, $2CaO.SiO_2$ and $3CaO.Al_2O_3$, and that the break in the cooling curve was due to the solidification of the undercooled $3CaO.Al_2O_3$, perhaps with $2CaO.SiO_2$, at the quintuple point. Rankin and Wright showed further that a mixture of the composition $8CaO + Al_2O_3 + 2SiO_2$ does not melt at the temperature of 1382°, and even at 1600° is only partly in the liquid state.

Janecke[61] has published several further papers on the constitution of cement, and has continued to believe in the existence of the compound $8CaO.Al_2O_3.2SiO_2$. He calls attention to the form of the crystals of this material as being needle-like or prism-like, and weakly birefracting. The various forms of $2CaO.SiO_2$, he states, have either strong birefraction or granular form, while the compound $3CaO.SiO_2$, according to Wright, crystallizes in grains.

Wetzel's Experiments

A number of interesting investigations bearing on this subject, in which polished sections of clinker were examined microscopically, were reported by Wetzel.[62] Heat treatments were given mixtures of pure $CaCO_3$, Al_2O_3 and SiO_2, and also of commercial cements. Cooling curves were determined and sections of clinkers were polished, etched with hydrofluoric or hydrochloric acid, and the crystals identified. The field of Janecke's compound was especially studied, and Wetzel arrived at the conclusion that this "compound" could not exist. Only at temperatures of 1670° and above could he obtain the elongated crystals typical of Janecke's $8CaO.Al_2O_3.2SiO_2$, but upon making an anlysis of this material it was found not to coincide with the above composition. Neither was it possible for Wetzel to produce these crystals unassociated with the usual forms of $2CaO.SiO_2$ and $3CaO.SiO_2$. The needle form of crystal was found to increase up to temperatures of 1800°, but as it could not be obtained free of other crystalline material Wetzel regarded it as "only a member in a series of solidifications."

Glasenapp[63] in 1913 held that the study by the Geophysical Laboratory was altogether inconclusive, and expressed the view that alite is "an isomorphous mixture of $2CaO.SiO_2$ and $3CaO.Al_2O_3$ in which the molecules of the components can occur side by side." On the other hand, Endell[64] accepted the existence of $3CaO.SiO_2$ in cement, although no data were presented in opposition to the views of Janecke. Endell regarded the work of Rankin and his collaborators as authoritative.

Kuhl[65] has contributed a number of papers to the controversy on the constitution of alite. In 1921 he stated that he agreed with the Americans that tricalcium silicate may be obtained from a cement melt, and that it is the main ingredient of alite which "forms an isomorphous compound with varying amounts of lime-rich aluminates."

Dyckerhoff's Views

Exception was taken to this view by Dyckerhoff.[66] This investigator performed a number of experiments on the pure constituents, $CaCO_3$, SiO_2 and Al_2O_3, using the ternary diagram of Rankin as the basis for his study. He made exact mixtures corresponding to the compounds $3CaO.SiO_2$ and $2CaO.SiO_2$. These he moulded into narrow rods and, by holding the ends in an oxyhydrogen flame, caused drops to flow off from the preparation. The drops were quenched in mercury and examined as thin sections under a polarizing microscope.

The $3CaO.SiO_2$ mixture was prepared in the above manner and then held at 1200° for five days. Dyckerhoff reports that the mass was then homogeneous and consisted only of the compound $3CaO.SiO_2$. The optical data agreed with those reported by Rankin except that the crystals appeared to be monoclinic instead of orthorhombic. Dyckerhoff reported, however, that this compound did not set and was not decomposed by water. He accordingly concluded that $3CaO.SiO_2$ is not the active hydraulic constituent, that is, the alite, of clinker. The $2CaO.SiO_2$ was studied, and the alpha, beta and gamma modifications prepared. Rankin had previously found the alpha form to be stable at temperatures above 1420°, the beta between 1420° and 675°, and the gamma below 675°. Dyckerhoff first believed the change from the alpha to the beta modification to be slow while the beta to gamma transformation was rapid, but later he reported that the former transformation is very rapid while the latter is sluggish and easily passed by rapid cooling.

Furthermore, the beta $2CaO.SiO_2$ was found to be hydraulic, and commercial cements were found to set and harden in accordance with the proportion of the beta $2CaO.SiO_2$ present. Consequently, Dyckerhoff concludes that this compound is the alite of cement clinker.

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[60] G. A. Rankin and F. E. Wright, *Z. anorg. Chem.*, *75* (1912), 63.

[61] E. Janecke, *Z. anorg. allgem. Chem.*, *76* (1912), 200, 357; *Protokoll* Veriens Deut. Portland Cement Fab., *36* (1913), 273, *37* (1914), 160; *Z. anorg. allgem. Chem.*, *93* (1915), 271; *Zement*, *14* (1925). 272.

[62] E. Wetzel, *Protokoll* Veriens. Deut. Portland Cement Fab., *35* (1912), 217; *36* (1913), 347; *37* (1912), 145.

[63] M. von Glasenapp, *Protokoll* Veriens Deut. Portland Cement Fab., *36* (1913), 313.

[64] Kurd Endell, *Protokoll* Veriens Deut. Portland Cement Fab., *37* (1914), 221.

[65] Hans Kuhl, *Tonind. Ztg.*, *38* (1914), 537; Kuhl and Knothe, "The Chemistry of Hydraulic Cements," Leipzig, 1915; *Protokoll* Veriens Deut. Portland Cement Fab., *44* (1921), 109; *45* (1922), 98; *Zement*, *13* (1924), 512.

[66] Walter Dyckerhoff, *Zement*, *13* (1924), 455, 467.

Dyckerhoff[67] reported later that by heating a mixture of 2½ CaO to 1 SiO_2 he obtained a mixture of $3CaO.SiO_2$ and $2CaO.SiO_2$, but on holding this mixture at 1400°, and quenching, he found no $3CaO.SiO_2$, and noted a change in the birefraction of the $2CaO.SiO_2$, it being now lower than that of pure $2CaO.SiO_2$ but higher than that of $3CaO.SiO_2$. On longer heating at 1400°, and slow cooling, there remained $2CaO.SiO_2$ and CaO. From these observations Dyckerhoff concludes that "at high temperatures appreciable quantities of lime go into solid solution and lower the birefraction. On slow cooling, the lime crystallizes out." Thus he believes that the alpha or beta forms of $2CaO.SiO_2$ dissolve CaO, while the gamma form does not.

Notwithstanding his belief in the existence of a solid solution of CaO and $2CaO.SiO_2$, it is recalled that Dyckerhoff also accepts the existence of the compound $3CaO.SiO_2$. By many experiments he corroborated the data of Rankin, and found further that the compound $3CaO.SiO_2$ begins to form at 1450°. The speed of formation was found to increase with the temperature until, at 1800°, it was complete in a few minutes.

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[67] Walter Dyckerhoff, Dissertation, Leipzig, 1925. *Zement, 13* (1924), 681; *14* (1925), 3, 21, 60, 103, 120, 140, 172, 200.

The conclusion of Part VII, the final chapter in this series, will be published in the February issue

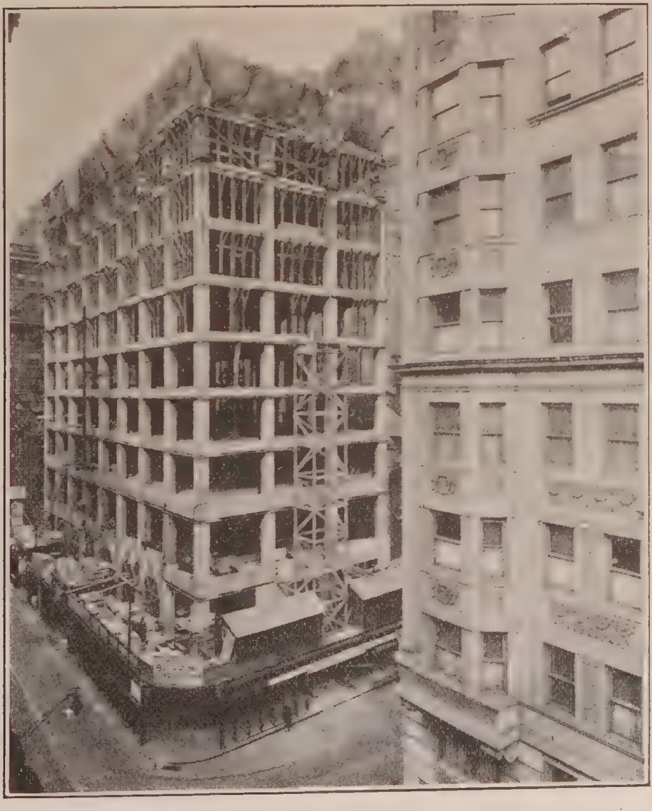
Philadelphia Skyscraper Built During Winter in Record Time

THE construction of a 15-story reinforced concrete office building at the corner of Fifteenth and Locust Streets in Philadelphia, during the winter of 1925-26, presents two claims for distinction.

First, the building was constructed in record time, only eight months being the remarkably short time required. Second, this accomplishment was made in spite of cold weather.

So rapidly was the construction of the structural frame rushed that the supports at one time were six floors below the floor then actually being placed. The normal length of time to keep the forms intact on a job of this sort is two weeks, indicating that the structural frame was erected at the rate of six floors in two weeks.

Work on the first floor started on the last day of the year. By applying the standard methods of winter construction, such as the use of tarpaulins, salamanders, etc., the concrete was placed with adequate protection against the weather.



Construction under way, showing the winter protection methods used

The completed building

This job adds another example to the long list of successful winter jobs. It has the added distinction of being completed in an unusually short time even for warm weather work.

Gravell & Hall of Philadelphia were the architects and F. V. Warren & Company the contractors.

Concrete Tile Used in Roof Slab

Wide-Awake Products Man Promoted New Use for His Products and Got More in the Job—Several Large Buildings Use His Tile

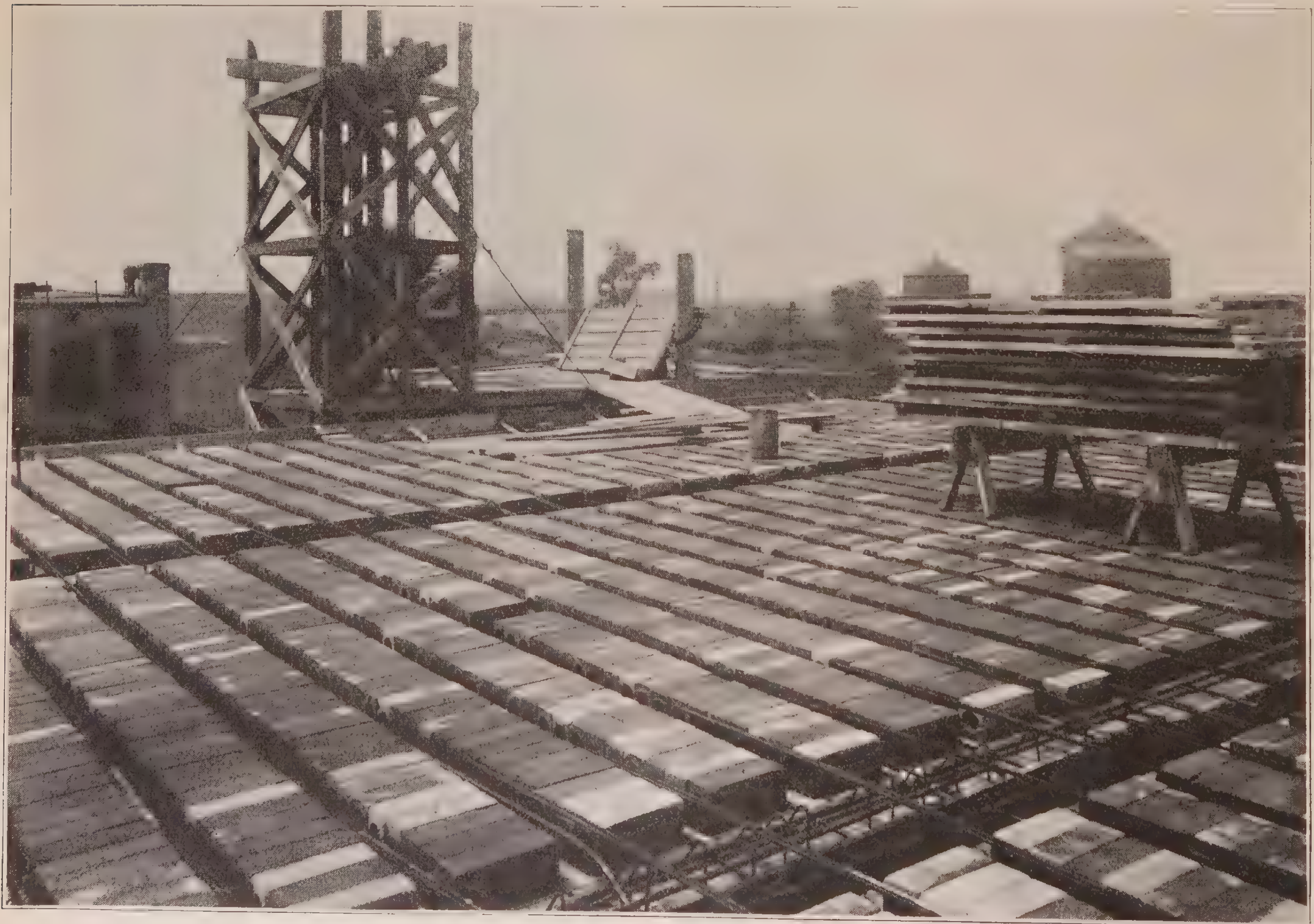
THE National Concrete Corporation, of Benton Harbor, Michigan, producer of Duntile, is doing things in an unusual way. According to H. W. Sewall, who is in charge of the plant, they are opening up new markets and new uses as fast as possible. An instance of the sort of things this company does carries a suggestion for every products manufacturer, even though the units manufactured by this company are of a rather different nature from the units manufactured by many other plants.

When the Brammell Supply Company, of Benton Harbor, decided to put up a new building they insisted on fireproof construction. They had already selected Mr. Sewall's tile for the wall, when the subject of interior wall facing and roof construction was brought into consideration. The interior wall finish problem was quite easily solved when spray-faced Duntile was selected. That added to the order placed with the National plant. Then the owners wanted a good fireproof roof and were thinking in terms of monolithic concrete when Mr. Sewall suggested a new method, and that method was adopted.

The roof was constructed of a combination of reinforced concrete and Duntile in an interesting way. First, the floor forms were erected just as for a flat slab. Then parallel rows of 4 x 4 x 12 tile were laid on the forms, with four-inch spaces between the rows, as shown in the illustration. Next the reinforcing steel was laid between the rows, just as in floor construction where steel pans are used. Concrete was then placed, forming reinforced concrete beams with the tile used as fillers. The concrete worked into the air cells of the tile and effectively keyed them in place. The result was a four-inch concrete roof slab with no more weight than is ordinarily obtained with a two-inch slab.

The basement walls of this building were of 8 x 8 x 12-inch Duntile laid up double, the first story wall was of 5 x 6 x 12 units laid up in the same way, while the wall of the top story was built of 5 x 8 x 12 tile laid up single thickness. Glazed tile on the interior eliminated the need for plastering or painting, these units having been finished to order after curing by spraying with the spray gun. This afforded a smooth, hard surface that has a good appearance.

Another large building utilizing tile from this plant is that of the Cabernette Manufacturing Corporation, of Michigan City, Ind. This is a one-story factory building 500 feet long and 100 feet wide. The walls of this struc-



Roof construction, on which Duntile was used as a part of the roof slab. Note the placing of the units and the reinforcing ture called for about 200,000 tile. The P. H. Lorenz Company, builders, have had quite a bit of experience with these units and selected them for this structure because of their economy. In Toledo, Ohio, for instance, this contracting firm recently erected a large building for the John H. Deere Plow Company, and through the use of concrete tile saved the owners 30 per cent over the cost of the structure had it been erected of brick and clay tile. The National company is planning to furnish their units for the new Premier Hotel soon to be erected in Benton Harbor, and this will call for 100,000 tile.

Glazed tile on the interior of the same building

Contract for University of Michigan Stadium To Be Let in 1927

The athletic program of the University of Michigan includes the erection of a stadium, on which work was started in August. It will consist of a depressed bowl quadrangular in shape, with curved corners, largely excavated into the ground. The seating capacity will total 72,000, with some special features regarding entrances and exits.

The site is on a slight side hill so that the rear concourse or top of the deck on the north, west and south sides will be banked up in such a way that spectators can approach their seats directly on the ground and over the rear concourse. Seats along the easterly side will be approached from beneath portals in the deck at an elevation of about 18 ft. below the level of the concourse. Entrance to the field proper will be through a tunnel at a still lower elevation, with the team rooms and dressing rooms on the same level. The entire field will be drained by a 48-in. concrete sewer.

Contract for the preliminary work, consisting of more than 200,000 yards of excavation, together with embankment, grading of the site and construction of concrete footings and sanitary sewer were awarded to Raymond A. Mercier, Detroit, with the understanding that it would be completed by December 15th, 1926.

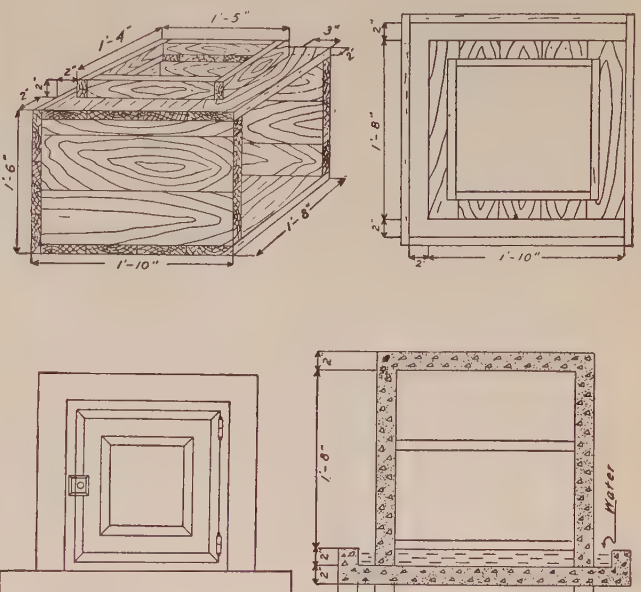
The general contract for the construction of the stadium proper will be let some time early in 1927 and the entire operation completed in time for the football season of 1927.

A Correction

In the article, "Winter Construction as Applied to Reinforced Concrete Work," by Virgil L. Johnson, appearing in the December issue of CONCRETE, the temperature during construction work at Toronto, Ontario, Canada, should have been given as 10 degrees below zero instead of 50.

An Iceless Refrigerator That Is Easy to Make

The concretor living in the smaller town will find a demand for all sorts of odd jobs that may be done with concrete while a larger project is under way for a rural customer. Among the many small things that may be built to utilize surplus cement and aggregates is an iceless refrigerator of concrete that cools food by means of surface evaporation. The drawings will show the forms required. They are easily improvised from wooden boxes if the expense of specially cut forms is unwarranted. If made in the size shown, the box will require a 1:2:3 mix of ½ sack of cement, one cubic foot of sand, and 1½ cubic feet of gravel. About 16 square feet of mesh reinforcing would be needed. Nailing plugs may be used to permit supporting shelves. A close-fitting wooden door with icebox hardware is hung in the opening and made tight with any good weather-stripping. The water tray may be made of waterproofed concrete as shown, or it may be of galvanized iron or sheet zinc, if such a tray is already on hand. The tray is kept filled with water, which is drawn up the exterior walls and constantly evaporated, cooling the contents of the box.



Details of forms, door and cross section of refrigerator

Plans Progressing for Southwest Road Show

The United States Bureau of Public Roads is to have an extensive exhibit at the Second Annual Southwest Road Show and School, according to a recent news item. This show and school, which has been provided for the benefit of highway builders of the southwestern states, will be held in Wichita, Kansas, on February 22, 23, 24 and 25, 1927. More than 30,000 square feet of floor space has been allotted to the Good Roads School exhibits alone, and two theaters, one seating 2,000 and the other 5,000, have been allotted to the affair. The coming school and show promises to be a very worth-while affair, especially since it will serve many who could not undertake the longer journey to Chicago.

A Description of Chicago's Double-Deck Downtown Boulevard

WITH this issue, we present the first of a series of articles describing the recently completed Wacker Drive in Chicago.

THIS, one of the largest single civic projects ever undertaken, is remarkable, not only for its magnitude and for the rapidity with which it was completed, but also because of the unusual design and construction problems that were met and solved as the work progressed.

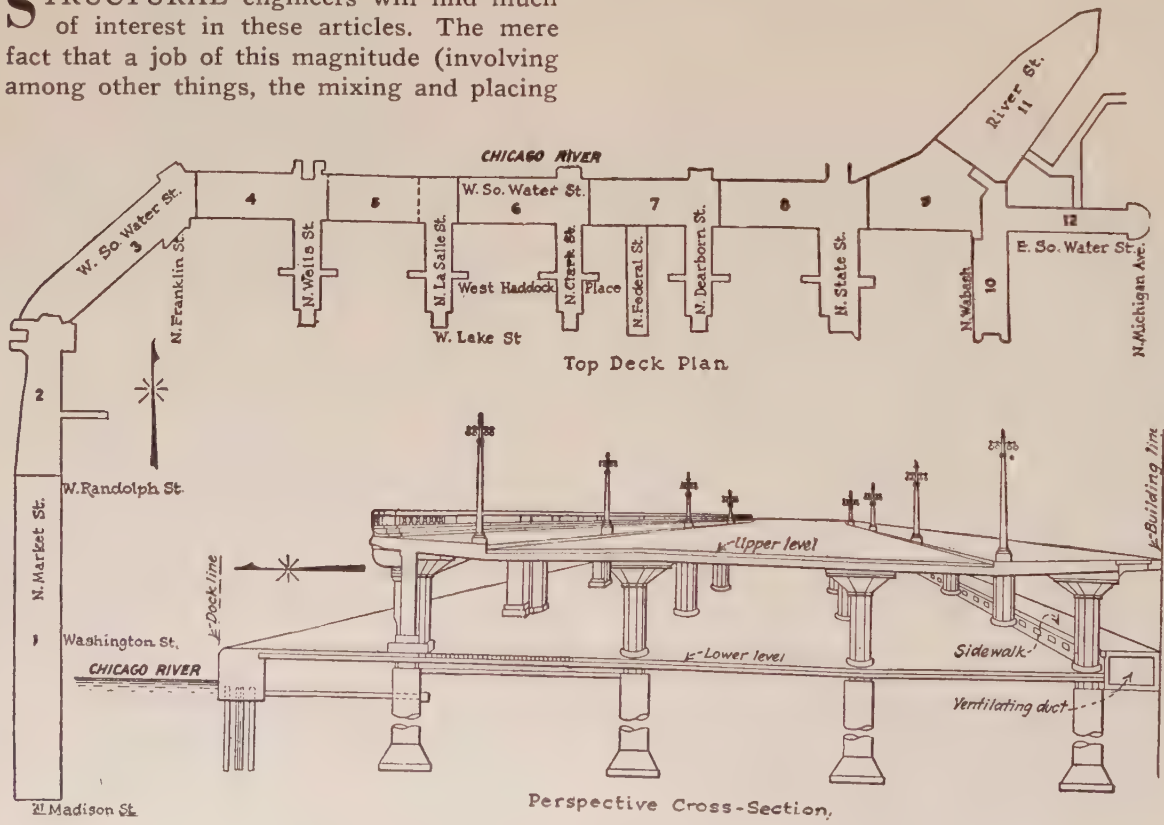
THE project is of interest to the highway engineer because it is probably the first double-deck traffic way ever completed within the heart of a big city. Its construction is of inestimable value to the city from the standpoint of unraveling the traffic tangle in Chicago's "Loop." By transforming the old commission market district into the highest grade business property, it multiplied property values many times and at the same time made possible a saving estimated at $6,500,000 yearly by eliminating the commission market traffic from the "Loop." The lower level will carry industrial traffic to the extent of 5,000 vehicles per day.

STRUCTURAL engineers will find much of interest in these articles. The mere fact that a job of this magnitude (involving among other things, the mixing and placing of 120,000 cubic yards of concrete) was completed in the short period of two years, gives it distinction.

PRACTICAL methods of controlling the quality of the concrete were developed and followed throughout the job. The favorable results obtained from the test specimens and the methods adopted in making the tests and checking the quality of the concrete, are explained in the first article, beginning on the opposite page.

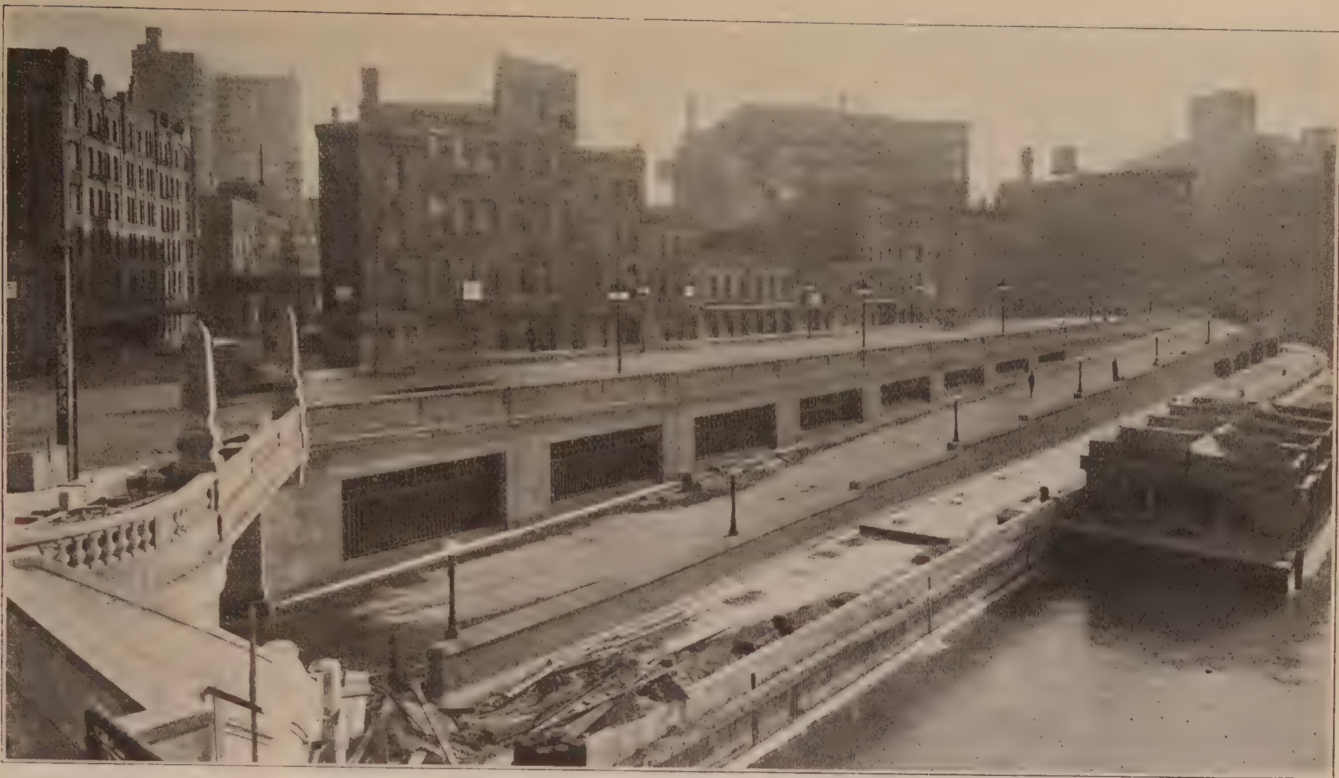
THE second article, to be published in an early issue, will present the design features of this unusual structure. Because of the many underground public service lines, tunnels, etc., interesting design problems were encountered. Difficult intersections and long spans necessitated other original designs.

This article will be followed by a description of the unusual construction features encountered and the series will close with a general article describing the engineering organization that carried the job to completion and the correlation of office and field activities.



Top Deck Plan

Perspective Cross-Section



A general view of Chicago's new double deck boulevard, illustrating one of the ramps

Building a Two-Level Street in Downtown Chicago

A Description of the Construction and Design Features of Wacker Drive—An Unusual Concrete Construction Job

By R. W. PRIEST
Field Testing Engineer, Board of Local Improvements, Chicago

Part I—Design and Control of the Concrete Used

IN the construction of Wacker Drive, the engineers in charge of the work were faced with a combination of requirements that gave rise to some unusually interesting developments in quality control of concrete.

The design of the structure, together with the time limit set for its completion, materially influenced the character of the specifications and placed restrictions on the methods of construction that could be adopted and that would insure a completed project of the highest quality.

From an engineering standpoint, the improvement is primarily a big outdoor, reinforced concrete structure and, although many engineering problems were involved, it was that portion of the work that involved the proportioning, placing and testing of the concrete, that made the greatest demand on the time and efforts of the engineers in charge.

It was the desire of those responsible for this project to build a structure that would not only stand for strength, permanence and durability but for architectural beauty as well. Therefore, in view of the many failures or near failures that have occurred in recent years in stadium, viaduct and other similar structures, it was realized that the closest cooperation between office and field engineers, the strict enforcement of rigid specifications as to workmanship and materials, never-ceasing vigilance, the use of the most modern approved equipment and scientific control of concrete had to be employed and specified to reach that objective.

Wacker Drive has been built in the very short period of two years. This is a remarkable accomplishment in the face of the tremendous difficulties involved.

Organization

The size of the job and the desire to maintain a rigid system of inspection and control, made it imperative that part of the field forces devote its entire time to the work of inspection and tests. It was realized that the inspection department could not function to its fullest capacity and efficiency without the aid of a closely coordinating force, that of the testing division. This department was therefore organized and operated throughout the entire period of construction. Under the supervision and direction of the field testing engineer the work of inspection and testing was carried out by a number of inspectors.

Specifications and Equipment

The concrete specifications in general are based on the Joint Committee's Standard Specifications. They call for carefully graded stone for coarse aggregate. Difficulty was experienced in finding a suitable material in the Chicago market, due, it would seem, to the fact that engineers generally do not insist on the proper grading of the coarse aggregate, although it is well recognized that this is an important strength factor.

Only one kind of cement was used in order to maintain uniformity. The specifications call for cement meeting the A. S. T. M. specifications with the additional requirement that the strength at 28 days shall be at least 20 per cent greater than at 7 days. The concrete mixture for the most part was a nominal 1 to 6 proportion with 7 gallons of water per sack of cement. The contractor was permitted to increase the water content of any mix so long as the water cement ratio remained constant.

The use of the sand inundator was specified, the purpose being to eliminate any uncertainty as to the moisture content of the sand.

Except in extreme cold weather, the time of mixing was specified as 1½ minutes from the time the last material of a batch went into the mixer until the first came out.

The consistency of the concrete was governed by the requirement that the slump was to be between 2 and 4 inches in order to insure the maximum density.

Cold Weather Work

The specifications contained very minute instructions as to the procedure to be followed when concreting in cold weather. Thus for a 1 to 6 concrete, the amount of cement per cubic yard was to be increased from 6 to 9 sacks; the mixing water or water content was to be reduced from 7 to 5.8 gallons per sack of cement and the time of mixing was to be increased from 1½ minutes to 2 minutes for all concrete placed during the months of December, January and February; a sliding scale being provided for the months of October, November, March and April.

This was done in order to insure a uniform initial strength for all concrete placed whether in winter or summer, and to secure the high strength at 30 days that would permit the opening of the section to traffic in this period.

Provision was also made for heating the concrete materials and for preventing the fresh concrete from freezing when the temperature was below 32 degrees F.

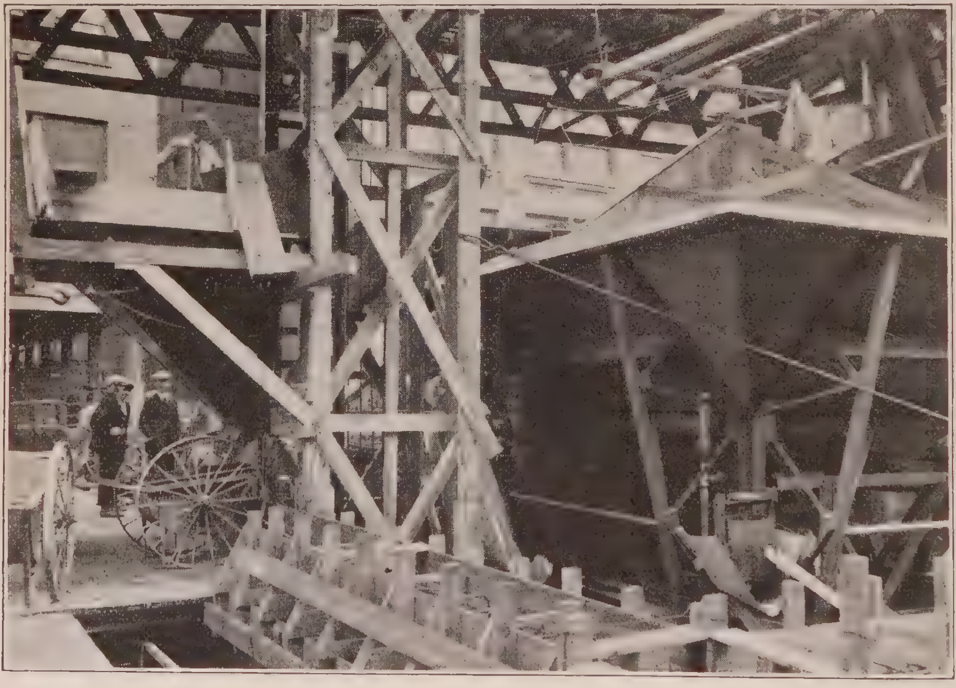
Lime Used

The specifications provide for the use of 8 pounds of hydrated lime per sack of cement. This was found to produce a more workable, plastic consistency in the mixture and also to fulfill its fundamental purpose to produce a denser, watertight concrete.

The concrete was mixed in rotary batch mixers of 1 yard capacity, conveyed to a receiving hopper by a belt conveyor and loaded into concrete carts or buggies from which it was finally deposited in the forms.

The aggregates were measured in batch hoppers carefully calibrated to correct cubic footage of material for the desired mixture.

The work of the inspection and testing department resolved itself into seven distinct divisions, each in itself of considerable importance in relation to the work.



The concreting plant. The excess water tank is seen in the lower right hand corner

Inspection of Cement

The first division was the work of sampling cement, reinforcing steel and any other materials whose qualities are subject to variation.

In general, Universal Portland Cement has been used on all concrete work. Bins having a capacity of 25,000 barrels were assigned for cement plant storage of inspected cement for this project. Samples of cement were taken from the conveyor belt at 15-minute intervals at the time the bins were being filled. Two duplicate composite samples were taken for every 200 barrels loaded into a bin. The loaded bin was then sealed by an inspector for the Board of Local Improvements and no cement was withdrawn until the 7- and 28-day tests were available from the samples taken.

One set of the duplicate samples taken was tested at the laboratory of the Board of Local Improvements and the other set by the Testing Division of the Department of Public Works.

Inspectors were stationed at the mill at Buffington to break the seal on the bins, count the bags loaded on each truck, reseal the bins, and issue tickets of inspection to truck drivers. These tickets contained the ticket serial number, the load number, time of departure, truck license number, the ticket invoice number, and the date. They were sealed in an envelope of the Board of Local Improvements and marked, City Inspector. No cement was accepted on the job unless accompanied by one of these tickets, sealed. The information was checked and if found authentic by the receiving inspector the cement was unloaded and used.

Inspection of Other Materials

All metals required for the improvement, such as structural steel, rivet steel, reinforcing bars, spirals, wire mesh, cast iron, steel and wrought iron pipes were inspected at the place of manufacture by a representative of the Board of Local Improvements.

From time to time two duplicate 18-inch samples of each size of reinforcing steel were taken from stock piles on the job and check tension and bending tests were made. The specifications provided for the use of intermediate grade of reinforcing steel with a pull test of between 70,000 and 85,000 pounds.

Prepared expansion joint material, asphalt sand filler and paint were also given rigid tests.

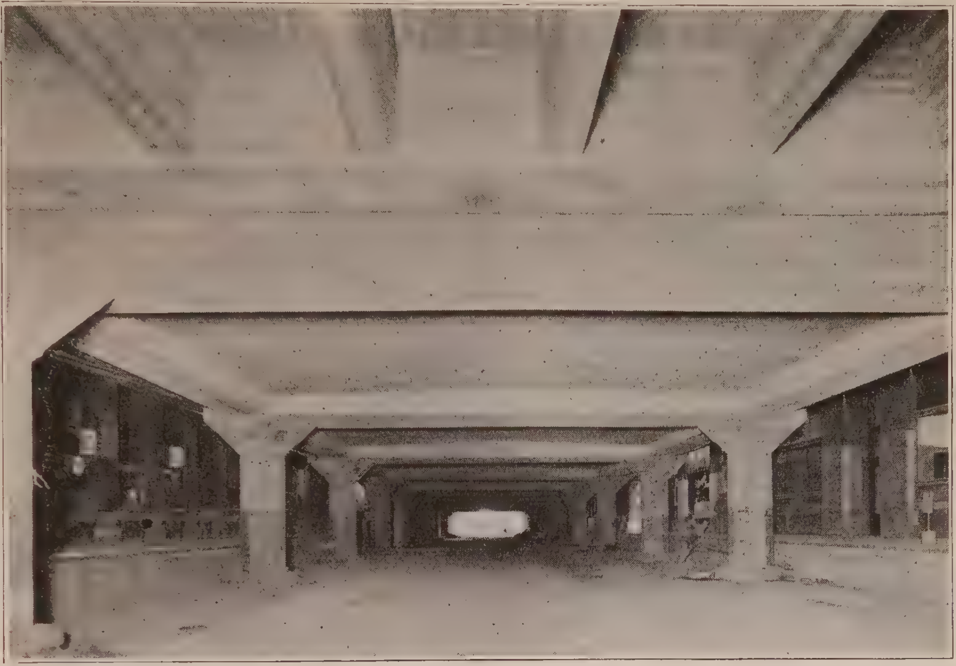
Selecting Aggregates

The second division comprised the work of selecting from the many aggregates submitted by the contractor those best suited to produce a strong, dense, workable concrete, that would satisfactorily and indefinitely withstand river-front exposure.

The coarse aggregate was screened to determine the grading, washed to determine the quantity of dirt, and examined visually to detect the presence of poor quality material. From an average of the sieve analysis it was found that the limestone accepted as meeting the specification, had a fineness modulus of 6.84. The fine aggregate was tested much in the same manner with the addition of the calorimetric test for organic impurities. The accepted sand had a fineness modulus of 2.86.

Design of Concrete Mixtures

The third division is the work of combining the selected aggregates in the most advantageous way under the specifications to produce a strong, dense, workable concrete. Using the fineness modulus method as a basis, the materials were measured in dry rodded quantities for a range of mixtures from a nominal 1:2:4 to a 1:3:3 for a 1 to 6 specified proportion. For a dozen mixtures between the aforesaid range, 10 cylinders were made from each mixture, two samples being made on each of 5 different days. Thus 5 cylinders were available from each mixture for testing at 7 days and five were tested at 28 days. Each specimen was hand-mixed in the laboratory watertight pans and the record of quantities of materials used, the slump, flow and yield of each batch were kept. The cylinder specimens were cured in damp sand in the laboratory and average compressive strengths of each specimen for 7 and 28 days, together with all data taken from the batches, were considered. The mix showing the highest strength, good density and best workable nature was selected. It must be remembered that concrete may be strong and yet porous and may be very dense and yet low in strength. A nominal mixture of 1:2:33:3.67 was found to meet all of the requirements and specifications. This also was found to



The lower level traffic way, showing the two types of construction used for the upper roadway slab. Note the fine appearance of the concrete have the greatest strength and density and yet was of a workable nature. It was the mixture adopted and used for a specified 1 to 6 proportion and all measuring devices for aggregates were calibrated accordingly.

Field Inspection and Control

The fourth division and probably the most important was the work of field inspection and control. This consisted of enforcing all the rules that lead to the best possible concrete, such as: accurate measurement of materials, water control, proper time of mixing, proper placing of reinforcement and concrete and proper curing conditions. These rules are well established and must be rigidly enforced in order to insure a structure of the highest quality.

Mixing the Concrete

Stationary mixers on the job were equipped with a measuring batcher for the stone and an inundator for the sand. These devices were carefully calibrated and set to deliver the proper proportions of aggregate for each batch as predetermined by test. Where concrete was mixed in portable mixers not equipped with batch measuring devices, two sample wheelbarrows, properly measured, one for sand (allowing 20 per cent for bulking) and one for stone, were placed near the mixer in full view of the inspector and the men loading wheelbarrows.

In placing substructure concrete, two inspectors were assigned to each mixer. One man remained at the mixer and received cement inspection tickets, inspected the aggregates, checked the quantities of material entering the mixer for each batch and was responsible for the proper time of mixing.

The other inspector made an examination to see that structure conformed to the plans, inspected the quantity and placement of the reinforcing steel, inspected the forms and reinforcing steel for cleanliness, saw that the temperature and consistency of the concrete was acceptable and supervised the placing of the concrete.

In placing superstructure concrete in the slab, the work was so arranged that concrete was poured in a continuous operation from one expansion joint to another. This meant a 36- to 40-hour period of pouring and necessitated dividing the inspection forces into 8-hour shifts of 6 men each. One man was in charge of the inspection crew and his duties were to supervise the work of the men under him. He saw that the measuring devices for aggregate and water were properly calibrated, checked the temperature and consistency of the concrete and that the forms were properly constructed and clean. One man inspected the placing of the reinforcing steel, and two men inspected the placing and puddling or spading of the concrete. One man was stationed at the mixer to see that each batch was mixed a full minute and a half and that the proper amount of cement and lime were put into each batch. Another man's duty was to take samples of concrete, make slump tests for consistency and mould concrete test specimens.

Winter Inspection

In freezing weather during the months of November to March, inclusive, each inspector was provided with a good grade thermometer enclosed in a metal case, to be used in determining the temperature of the freshly mixed concrete. The thermometer was inserted into the fresh concrete at intervals in order to make sure that the temperature of the concrete as delivered from the mixer was about 80 degrees F. A record of the under slab temperature and air temperature in the working area were obtained by means of maximum and minimum thermometers or by recording thermometers.

In fast drying weather it was the duty of the inspector in charge, or the field testing engineer, to see that the concrete was protected against drying out and that it was kept moist from 7 to 14 days, depending on weather conditions. At temperatures above 50 degrees F. the surface of the viaduct slab was covered with about an inch of bank sand and kept moist for at least 10 days. Vertical surfaces were kept moist and sprinkled 2 or 3 times daily.

In winter weather when salamander heat was applied, the surface of the concrete was covered as soon as possible with about a foot of slough hay and the viaduct structure was enclosed with tarpaulins confining the heat to the working area of the under slab.

Field Testing

The fifth division was that of testing the concrete as

The appearance of the structure was an important consideration. Careful form work and careful placing of the concrete resulted in surfaces that met the requirements actually mixed on the job by the contractor. The concrete on the job may be variable and these tests are intended to be as near representative as the actual conditions on the job as could be obtained. This work included the obtaining of quantities of freshly mixed concrete, the making of the slump test, the making of 6 x 12-inch cylinder test specimens, the storing and curing of the cylinders and the testing of the cylinders under compressive load. The resultant strength tests of the field specimens were determining factors in deciding the time at which the contractor was allowed to strip forms and also in the opening of a section to traffic.

Field Specimens

Owing to the difficulty of obtaining field test specimens representative of the actual conditions of the work it was decided to make and cure specimens representing 3 different conditions of placing and curing.

The first condition is a more nearly perfect one than the actual existing condition on the project. The specimens were representative of the quality of the concrete being mixed, cured and broken by laboratory methods. Two samples of concrete were taken from the mixer during an 8-hour shift from which 6 6 x 12-inch cylinder specimens were made in the standard manner.

The cylinders were cured in the laboratory in damp sand at 70 degrees F. Two cylinders were broken for compressive strength at 7 days, 2 at 28 days and 2 were held for testing at some future period, either 6 months, 1 year, or longer, if desired. From these specimens we have the strength value which would be obtained were the curing conditions on the job as perfect as the conditions in the laboratory.

The second condition is that of the upper surface of the slab. Eight cylinders per 8-hour shift were made in paper moulds placed in a 2 x 4-ft. box on the upper surface of the freshly poured slab. As soon as they were made they were completely surrounded with fresh concrete. The box was cured and protected in a manner as similar to that of the slab as the weather conditions demanded, in warm weather by sand covering and wetting and by hay protection in cold weather. These cylinders were easily broken from the block by means of a bullpoint and sledge without injuring the cylinder itself. Thus we had 8 cylinders cured on the upper surface of the slab available for test from each 8-hour period. Two cylinders are tested at 7, 14, 21, and 28 days respectively.

The third condition was that existing below the slab. At the same time that the quality concrete (laboratory) samples were taken, two duplicate samples were taken from the same batch; representing four specimens for each sample. These specimens were made into cylinders and were cured and protected much in the same manner as the underside of the slab. If heating was required, they were made and kept in the heated area and protected with hay covering. If curing was required they were covered with sand and kept moist. Thus we had 8 more cylinders for each 8-hour shift available for testing. Two cylinders were tested at 7, 14, 21, and 28 days respectively. In a 40-hour period of pouring, it may be readily seen that 110 cylinders were available for testing. We believe that if the average of the 7-day values of the cylinders representing the three different conditions on the work tested 1,500 lbs. per square inch of compressive strength, then the concrete in the structure will also have a compressive strength of 1,500 lbs.

Test specimens of concrete work placed below the ground level were cured in damp sand in the field laboratory. After the initial set of the concrete, the test specimens were capped with neat cement or plaster of Paris before testing. All compression tests were made in a 200,000-lb. Riehle testing machine at the Testing Laboratory of the Department of Public Works.

Study of Tests and Test Data

The concrete in Wacker Drive has been of the highest quality, and is superior to concrete placed on many concrete projects, due largely to the rigid system of inspection and control enforced on this project. The following is a condensed analysis of 4,000 cylinders which comprised the majority of the tests: For concrete placed from April to October inclusive, of 1 to 6 concrete representing average tests of all cylinders cured under the 3 conditions for the years 1925 and 1926 the following average compressive strength was obtained: For 7-day test, 1,800 lbs. per square inch; for 28-day test, 3,300 pounds per square inch. The above is for the months when no heating was required.

For 1 to 6 concrete placed from November to March inclusive, representative of the average tests of all cylinders cured under the 3 conditions for the years 1925 and 1926, the following average compressive strengths were obtained: For 7-day test, 1,700 lbs. per square inch; for 28-day test, 3,000 lbs. per square inch. This gives us a grand average of all cylinders of 7-day test for the entire period of around 1,750 lbs. per square inch of compressive strength and 3,200 lbs. for the 28-day tests. Although it was the primary object to obtain high early strengths as well as ultimate strengths, high ultimate strength of concrete placed in all weather is proven in the fact that in one year the concrete poured in winter has proven to be equal in strength to concrete poured in summer.

Conclusions

Considerable difficulty was encountered at the outset, in securing satisfactory fine and coarse aggregates. It seems there is no coarse aggregate on the market in Chicago that is properly proportioned and, after considerable difficulty and investigation, we succeeded in securing a material that was so proportioned as to give us proper density, and strength.

The first attempts at proportioning the fine and coarse aggregate for a 1:6 mix were absolute failures in that we were unable at first to get concrete of sufficient strength for Wacker Drive. After months of experimenting, we discovered a mix that was both dense and extremely hard. The resulting tests gave a finished product with a strength in the neighborhood of 3,400 lbs. per square inch on the standard 6 x 12 cylinders, whereas the ordinary mixtures gave strengths from 1,800 to 2,000 lbs. and at the same time were porous, even though the water-cement ratio was kept constant.

The theory pursued by the engineers in charge was that the densest concrete would be the strongest concrete. The more nearly we could approach stone the better our resulting concrete. Stone weighed approximately 162 lbs. per cubic foot. The concrete we were using weighed approximately 154 lbs. per cubic foot or better.

Whether we should use limestone coarse aggregate or gravel coarse aggregate was one of the first problems we met. We abandoned the use of gravel for the reason that all samples submitted contained large amounts of granite or thin, elongated particles that had fissures in them.

The personnel of the Board of Local Improvements in charge of the work was as follows: John J. Sloan, president; T. A. Evans, chief engineer; Arthur Engh, assistant chief engineer; C. C. Wright, engineer of construction.

(Part II of this series will be published in an early issue)

Pre-cast Unit Construction Successfully Used in Great Britain

Aerocrete Curtain Walls Placed Between Precast Reinforced Concrete Monolith Columns

By J. GUSTAF V. LANG, E.E., M.E.

THE light weight and insulating qualities of Aerocrete have been taken advantage of in a rather interesting method of construction which has been developed by Captain C. W. Glover and utilized for several factories in Great Britain by the well-known consulting engineering firm of Walter Bridges & Company of London.

This method of construction has been found exceedingly economical and could, in the writer's opinion, be developed for and applied to many different types of structures. The fact that both the columns and the curtain walls are pre-cast, cuts down the time of erection to a very considerable degree, which is of as great importance in many cases as the direct saving in labor.

In view of the wide applicability of the underlying principles of this method of construction, and the extensive field that it opens up for the use of cement products in the form of Aerocrete and concrete, a short description of the method used by the above mentioned concern will, it is felt, be of considerable interest.

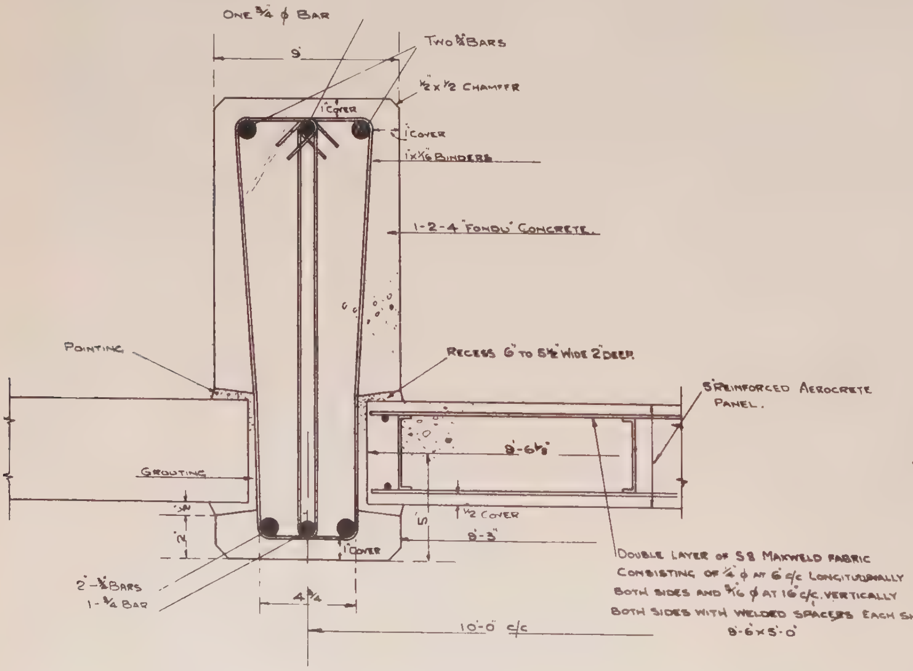
Factory Design

The accompanying drawings illustrating the method refer more particularly to the new plant of the Indestructible Paint Company, Ltd., at Park Royal, a suburb of London, and show the laboratory building of this plant and some details of the monoliths and the panels. As will be seen, this is a one-story building. The construction was started by laying the floor and by digging pits for the columns. The columns, which, it will be noted, are designed with a substantial foundation foot extending inward, were placed on 10-foot centers. Reinforcement in the standard column, as shown in the detailed drawing, consists of six ¾-inch round bars tied together. Recesses of 5½ to 6 inches width and 2 inches depth are provided for the panels. The reinforced Aerocrete panels measure 9½ by 10 feet. They are reinforced with a welded fabric consisting of ¼-inch rods placed at 6-inch centers horizontally and 5/16-inch rods at 16-inch centers vertically. Two sheets are held by welded spacers about 4 inches apart with a cover of about ½ inch of Aerocrete, making the total Aerocrete panel 5 inches thick. After the Aerocrete has set sufficiently, a ½-inch cement mortar facing is placed on the surface which takes the place of stucco.

The molds for the panels consist of a simple frame that is laid directly on the floor. The reinforcement is hung in the mold and the panel is cast. Where ventilators, windows or doors are required, they are cast into the panel as shown in the detailed section of the drawing.

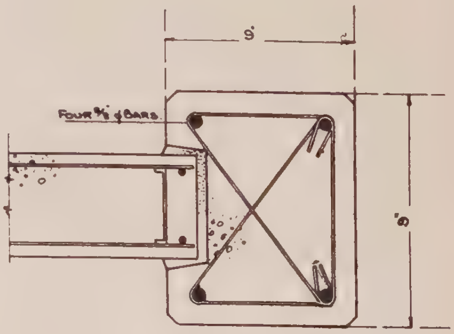
Columns

Whereas the panels were cast in Aerocrete, the columns were cast in alumnite. By the use of alumnite it was possible to cast a column one day and raise it into position the next. After the erection of the corner column, set in cement in the pit already provided, the next column was placed in the corresponding pit but not squared in position. Then the Aerocrete panel cast at this particular location was raised into position and fitted into the recess of the corner column. The second column was then squared up with the panel fitting into the corresponding recess,

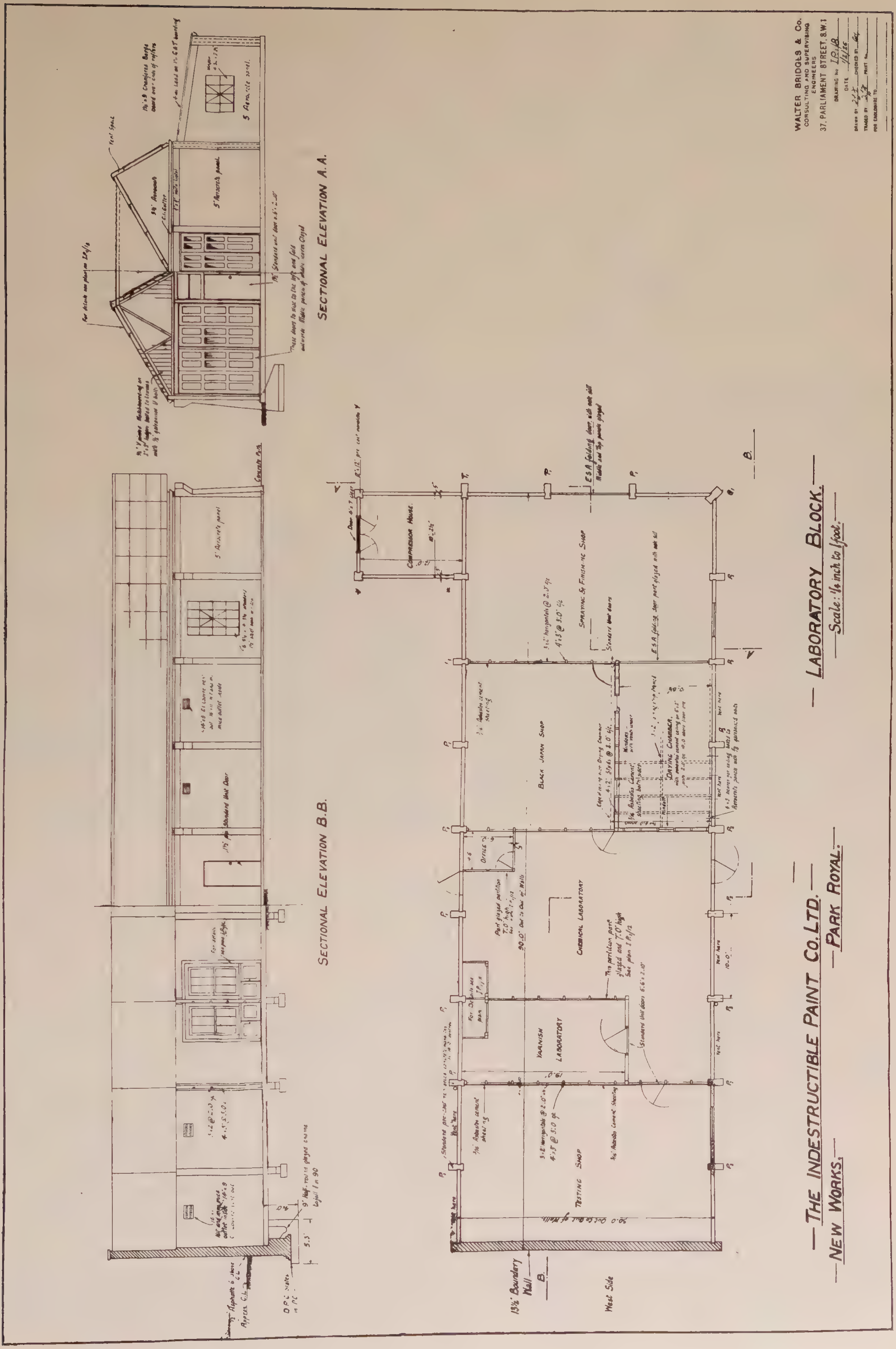


ONE ¾ ϕ BAR
TWO ⅝ BARS
9"
½ x ½ CHAMFER
1" COVER
1" COVER
1 x 3/16 BINDERS
1-2-4 "FONDU" CONCRETE.
POINTING
RECESS 6" TO 5½" WIDE 2" DEEP.
5" REINFORCED AEROCRETE PANEL.
8'-6½"
GROUTING
½ COVER
5
8'-3"
1" COVER
2 - ⅝ BARS
1 - ¾ BAR
4¾
10'-0" c/c
DOUBLE LAYER OF S8 MAXWELD FABRIC CONSISTING OF ¼ ϕ AT 6" c/c LONGITUDINALLY BOTH SIDES AND 5/16 ϕ AT 16" c/c. VERTICALLY BOTH SIDES WITH WELDED SPACERS EACH SHEET 8'-6 x 5'-0"

DETAIL OF MONOLITH "P"

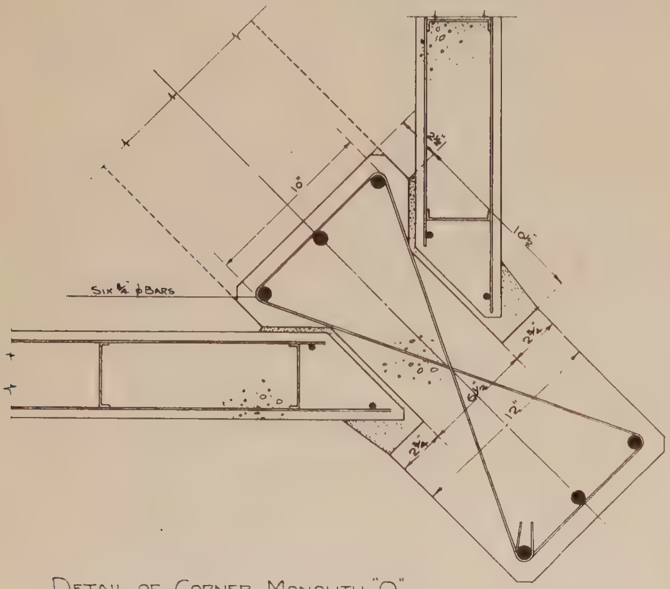


DETAIL OF MONOLITH "S"



Plan and section of the factory described. These general design featu res can be applied to many types of buildings.

after which the column was cemented in place. The panels were later lined up and the spaces in the recesses round the edges of the panels were pointed. The work then progressed in a similar manner until the entire building was completed. On top of the Aerocrete panel, resting on the columns, was cast in situ a 9 x 9-inch lintel as a support for the roof construction.

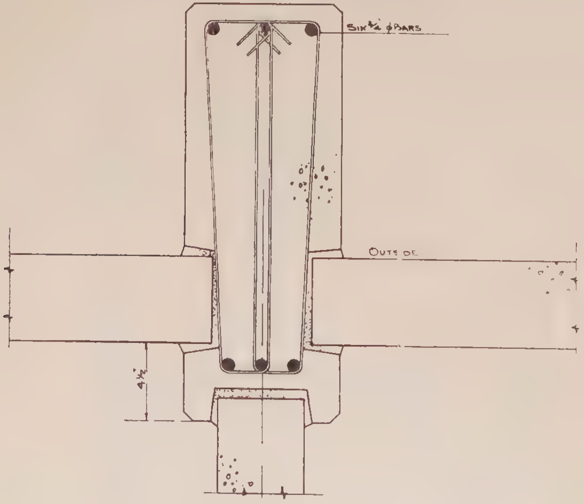


DETAIL OF CORNER MONOLITH "Q"

It will be noticed that most of the columns are alike with a few exceptions, such as the corner columns and the columns where more than two walls abut.

Has Wide Application

From the foregoing it will be easy for any constructing engineer to picture in his mind modifications of the same principle as applied to different types of structures. It is naturally just as easy to build curtain walls in this manner and raise them into position in buildings of several stories.



DETAIL OF MONOLITH "T"

The insulating quality of Aerocrete makes it possible to deal with considerably thinner walls in this material than if other materials were used. This, taken into conjunction with the lightness of Aerocrete, makes the total weight of a large panel relatively low, and the raising of such a panel becomes a comparatively easy matter. It is really these two characteristics of Aerocrete which make this type of construction so attractive. The lightness of course cuts down materially the necessary carrying capacity of the columns, which in turn to a considerable degree contributes to the reduction in cost. The great saving of time that is possible with this type of construction should not be lost sight of, since often the time element is of greater consideration than the cost.

Modern Dairy Plant

What constitutes a possible model for a dairy plant for the average moderate sized community has recently been erected by Raitt's Dairy, Inc., at Santa Ana, Calif. The building is reinforced concrete, covered with portland cement stucco. It contains the plant at which the milk is sterilized, bottled and stored, and the offices of the company. A unique feature of the plant is the room devoted to the handling of the product. This large room is open across the entire front, the windows glazed with plate glass, in order that people passing by may see for themselves the sanitary conditions under which the milk is handled. The floor and walls of this room are of white tile, while a special white ceiling, insulated to prevent condensation, is provided.

The equipment is of the latest type, and is for the most part covered with white enamel to match the room itself. Exposed metal is nickel plated. The cans of milk are received from the trucks and the raw milk is first weighed in a large weighing tank, from which it is piped to receiving vats, then passes steam coils raising the temperature of the milk to 142 degrees. The milk then passes into glass-lined tanks that permit the temperature to be maintained at 142 degrees for 30 minutes. These tanks are equipped with recording thermometers. The milk then passes a set of chilling coils, which reduce the temperature to 38 or 40 degrees, and from there to the bottling machines. A belt conveyor takes the filled bottles to the chilling room to await delivery. Equipment for washing and sterilizing receiving cans and returned bottles is installed. A little later a complete shop will be built in the rear for maintaining the fleet of delivery trucks operated by the concern. A display room is provided on the first floor, while the offices and locker rooms are on the second.

Increased use of concrete mixers on the farm is encouraged by the *Wisconsin Agriculturist*, in a recent issue, entitled "Farm Concrete Mixer Pays." The economy of a small gasoline-power mixer and the permanency of the construction is noted.

Retaining Wall Protects Highway

California Highway Commission Completes Massive Reinforced Concrete Sea Wall Which Protects Coast State Highway Where It Passes Along the Pacific Ocean Beach in Northern Ventura County

AFTER more than two years of effort a massive reinforced concrete seawall now protects the Coast State Highway in California where it passes along the ocean beach from Sea Cliff to Ranch El Rincon in northern Ventura County.

Completion of the work a few weeks ago ended a two-year battle to wrest from the surf a strip of land 6,400 feet in length and sufficient in width for the placing of an adequate pavement. The seawall was necessary because the only other available location is already occupied by the tracks of the Southern Pacific Railroad, and for the further reason that the light wooden trestle that formerly carried the highway was rapidly falling into a state of dilapidation that made it beyond repair.

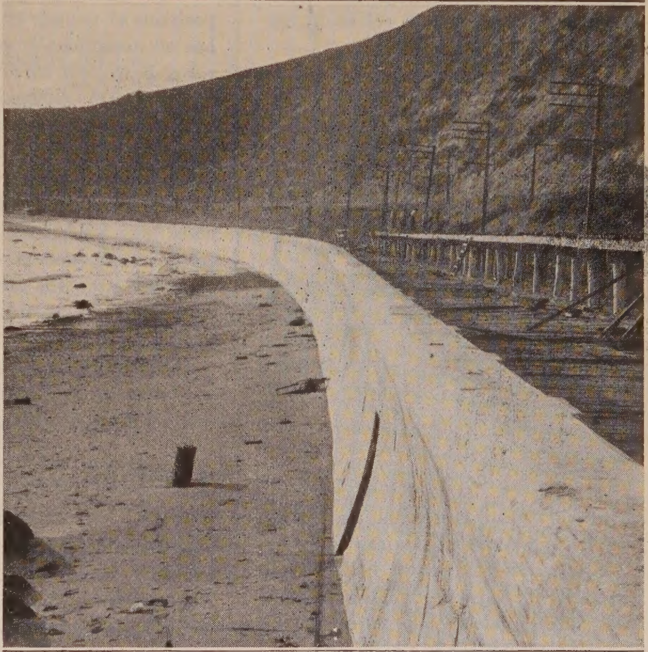
Nearly 16,000 cubic yards of high quality concrete went into the building of the huge seawall which rests on a firm foundation of shale and gravel beneath the sands of the beach, engineers explain. The wall averages 16 to 18 feet in height, but by far the greater portion is hidden from sight beneath the surface of the beach.

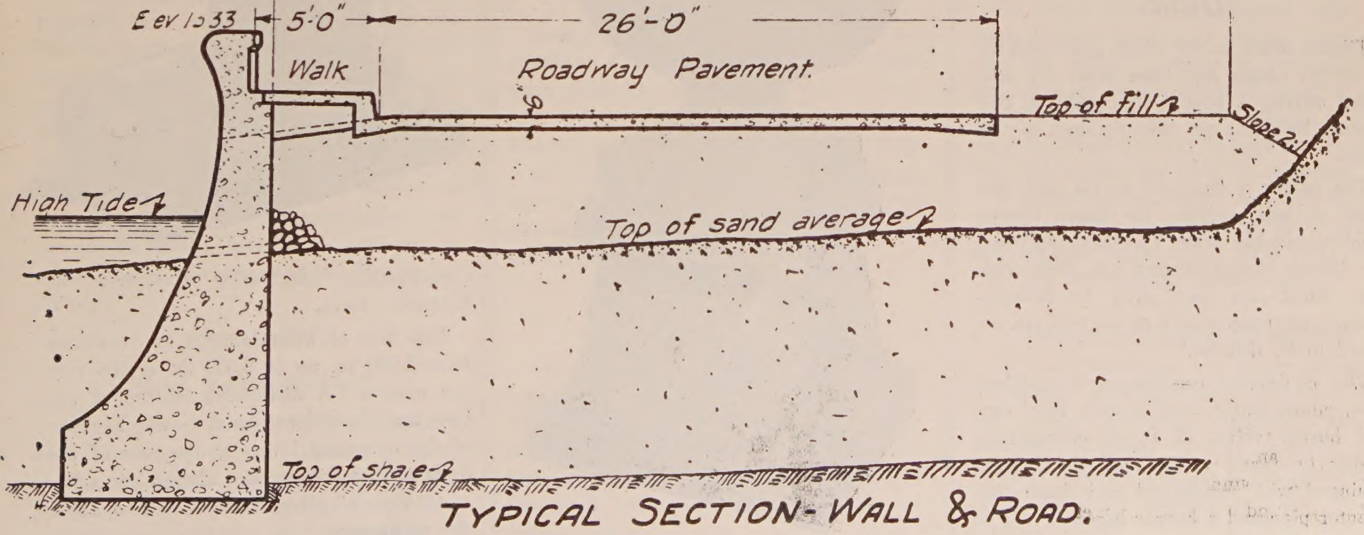
Wall Has Proved Effective

The Santa Barbara earthquake did no damage to completed sections of the wall, but did delay the contractor's operations. At another time during the construction the work was again interfered with by a coastal storm of almost unprecedented severity. Completed sections of the wall, however, proved its effectiveness as a protection for the highway.

The space back of the wall has been filled with sand and the old trestle removed. Removal of the trestle was done by Division VII, the Division of the Highway Commission with headquarters in Los Angeles, and proved a difficult undertaking because of the necessity for keeping the highway open for travel. Great credit for getting the job done with a minimum of inconvenience to the public is due Maintenance Superintendent Louis Prosper of Division VII. He and his crew kept traffic moving in rain and storm while work was under way.

When the fill back of the wall has settled sufficiently, there will be constructed upon it a pavement of ample width to care for the traffic over this section. In addition there will be parking space for vehicles and a sidewalk for pedestrians inside the parapet. The ends of the wall have been finished with ornamental stairways which lead to the beach. Completion of the pavement, which the California Highway Commission has planned for years, will transfer one of the worst sections of the Coast route into one of the most attractive.



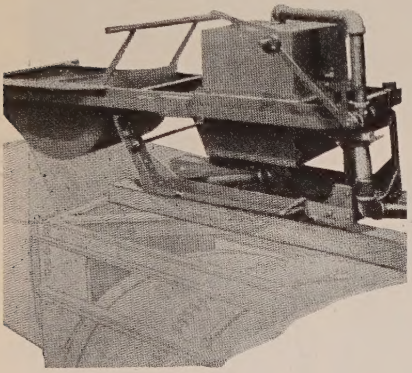


TYPICAL SECTION- WALL & ROAD.

New Equipment

Ahlers Strength Regulator Placed on Market; Automatically Proportions Batches According to Water-Cement Ratio Theory

Mechanical application of the water-cement ratio theory is the purpose of the Ahlers concrete strength regulator. Its use is particularly recommended to secure uniform strength and a steady, full capacity from the mixer in the field. By merely setting to the strength desired, the device makes all the calculations required by the water-cement ratio theory.



When being put into use, the tank is set for the strength determined from previous tests. Any number of old or broken bags is placed in the cement hopper, followed by the raising of the trip lever on the water inlet line, until it is caught on a pin, holding the valve open. The flow of water will shut off automatically when it is in desired balance with the cement. When the proper charge of water and cement is ready, the cement hopper is tilted and the water discharge lever is pressed down. The amount of moisture in coarse as well as fine aggregate is easily estimated, with a slight excess allowable, and is compensated for by the sliding of a weight to calibrated positions of pounds of water. The regulator has an exceptionally sensitive and accurate valve, is without moving parts, and may be locked at any setting.

Strengths within 5 per cent of requirements are regularly secured, eliminating the waste of averages ranging from 25 to 50 per cent. A saving on a recent job noted was $682.20 on 1,700 yards of concrete, or 40 cents a cubic yard. Twenty-eight-day strengths on three representative days averaged as follows: Sept. 9, 2,533 lb.; Sept. 18, 2,333 lb.; Sept. 28, 2,388 lb.

The Ahlers strength regulator is being marketed by the Barney-Ahlers Construction Co., New York City.

Heater for Tilting Mixer Drum

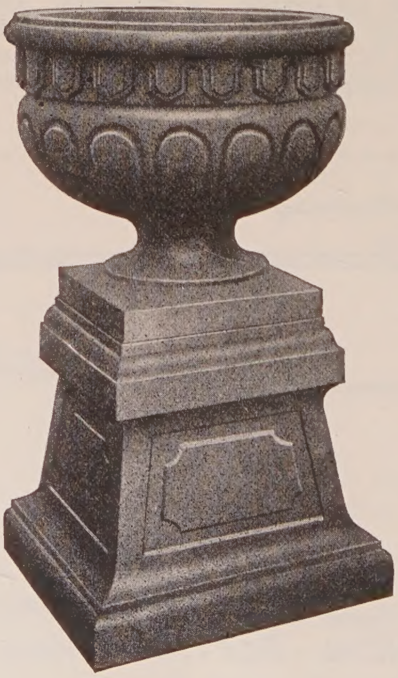
Tilting drum mixer users and users-to-be of the Jaeger and other types are now being offered a heater attachable in five minutes to either the yoke or shaft of the drum.

The heater is designed to tilt with the drum in any position, the flame always shooting into the drum. The manufacturers, the Hauck Manufacturing Co., Brooklyn, New York, say that even in freezing weather the temperature of the mix can be raised to 90 degrees.

The equipment consists of a seamless tank, pump, gauge, release cock, filler cap and burner valve, 12 ft. of oil-resisting rubber hose and unions and the burner equipped with windshield and flame distributor pipe and a burner bracket.

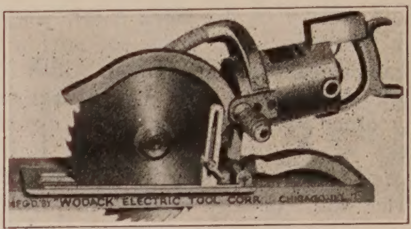
Sphinx Vase Mold New Product

An ornamental concrete mold, new and exclusive with the Concrete Equipment Co., Holland, Michigan, has been announced by that firm. The sphinx vase, massive yet symmetrical, stands 18 inches high, preferably on a pyramid pedestal.



New Electric Hand Saw Light Weight

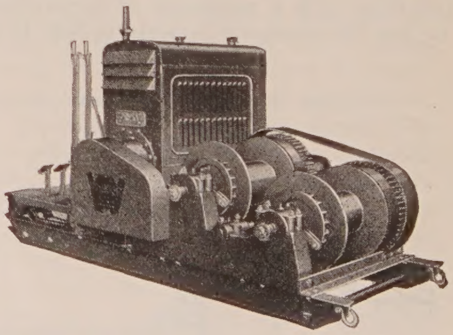
For sawing lumber for forms, many contractors are finding practical a new saw that weighs only twenty-four pounds and can be operated from an ordinary electric light socket. A timber 4x4 can be cut in less than two seconds, the manufacturers, the Wodack Electric Tool Corporation, Chicago, claim.



The saw is equipped with a motor large enough to drive an 11-inch circular saw, and also with a depth gauge, the latter to prevent damage to the saw when fitting form lumber on a concrete slab, or damage to other work under the piece being cut. This device should prove useful in channeling, beveling, and similar work where such a depth gauge is required.

Unit Plan Hoists Announced

Hoists built on the unit plan, i. e., designed so that an additional drum may be added, have been made available by the Construction Machinery Company of Waterloo, Iowa.



This line of hoists ranges in capacities from 2,000 lb. up to 8,000 lb. at 165 feet per minute. A distinctive feature of the two- and three-drum hoist is the banking of the operating levers at the rear of the hoist so that the operator always has a forward view of all operations in and about the equipment.

With the Manufacturers

INDUSTRIAL LITERATURE

Brace Booklet

Simplex Trench Braces, a piece of new equipment for the contractor, is described in a four-page booklet issued by *Templeton, Kenly & Company, Limited,* Chicago, who market the braces as well as *Simplex* jacks. The braces are made of steel and malleable iron and equipped with pipe, and may be adapted to any width of trench.

Batcher Bin Broadside

Commendations received from contractors about batcher bins that require no dismantling and are accurate and quick-working are published by the Heltzel Steel Form and Iron Company, Warren, Ohio, in a new broadside. Sectional bins, and separate batchers, two other products of this manufacturer, are also mentioned.

Catalog on Winter Tools

Its winter construction tools, such as heaters, torches, mortar heating pans, burners and salamanders, are the subject of a 24-page catalog published by the Aeroil Burner Co., Union City, N. J. One of the heaters is an elbow heater for tilting drum mixers, protected by a windshield.

Road-Building Catalog

Description, specifications and uses of complete gravel and road construction equipment of the *Russell Grader Manufacturing Company,* Minneapolis, Minnesota, are contained in a 64-page catalog recently issued by that firm. Accompanying photographs of illustrations are numerous well printed blueprints.

NOTES FROM THE FIELD

New Laboratory

The Pittsburgh Testing Laboratory has opened a new Detroit branch laboratory in the Lightner Building for the purpose of testing cement, concrete, sand, stone and allied material. The laboratory contains presses capable of making compression tests up to total load of 200,000 pounds on concrete products, as well as a cement testing laboratory including briquette storage and moist closet.

Kent Picks Florida Manager

In the interest of better service and to properly care for growing business in the Florida territory, the *Kent Machine Company,* of Kent, Ohio, announces the appointment of *Mr. C. R. Ott* as Florida district manager, with headquarters at Orlando, Florida.

Because of his background of experience as a concrete products manufacturer and former contractor, Mr. Ott is expected to prove of great assistance to the Florida industry.

Ideal Appointment

Announcement is made by the *Ideal Concrete Machinery Co.* of Cincinnati, Ohio, of the appointment of *Wylie Bros., Inc.,* 511 West Main Street, Olahoma City, Okla., as their representatives for that state.

Solvay Absorbs Agents

The Solvay Process Company has announced that since January 1 a new company known as the *Solvay Sales Corporation* has become the exclusive distributor of the products of the Solvay Process Company. The corporation has acquired the entire business of Wing and Evans, Inc., and has assumed, as principal, all contracts executed by the latter, covering products of the *Solvay Process Co.* All offices and branches of Wing & Evans, Inc., are being continued by the new company.

Heil Appointment

George Kuhlman, who has been branch manager of the *Heil Co.* in Philadelphia since 1922, has been named district manager for the New York and Philadelphia territories, with headquarters in New York.

Mr. Batchelder will be the assistant manager in the New York territory and *Charles Genther* assistant manager in charge of the Philadelphia branch.

Eberling Raises Price

The Eberling Machines Sales Company, Cleveland, Ohio, announces that the time has elapsed during which a special price of $6,500 was in force for an Eberling automatic brick machine. On December 1 the price was increased to $10,000, the former charge.

At the Road Show

Link-Belt Crane at Good Road Show

The exhibit of Link-Belt Company of Chicago at the Good Road Show in Chicago's Coliseum, will be in charge of a representative group of Link-Belters.

The new type K-42 All-Purpose crawler crane will be shown.

Truck Display

The Garford Truck Company will be found in Booth A-5. The exhibit will be the late Model 30, 1½-2 ton truck, upon which is mounted a 1½ cubic yard dump body, as well as the same model equipped with a Heil standard hoist and the dump body.

Clamshell Buckets

Bradley Badger Clamshell Buckets will be exhibited in space on the main floor off the Wabash Avenue entrance. Several new models will be shown.

T. L. Smith Exhibit Interesting

Of special interest at the show will be the T. L. Smith Co. 27-E (6-bag) paver which is now equipped with the Bowen One Shot lubrication system. This system insures proper lubrication of every bearing and therefore lengthens the life of the paver and reduces delays and repair costs. Instead of the every-day job of lubricating requiring half to full hour, the operator simply pushes a plunger and every bearing is oiled.

Road Show Exhibit

To better serve the industrial field in general, the Continental Motors Corporation has added a series of two-cylinder engines to its already complete line of fours and sixes. They will be introduced at the National Road Show to be held in Chicago the week of January 10 to 14, inclusive.

In connection with this, there will be on display the Red Seal industrial power units and engines, models P11, P20, P35, P56, P75 and P96 portable power units.

Highway Catalog-Directory

Highway engineers and others affiliated in highway work may secure copies of the 1927 *Road Builders' Catalog-Directory,* completed January 1, from Charles M. Upham, business director of the American Road Builders' Association, Box 1270, Raleigh, N. C.

Mixer Musings

Reported by "Joe"—The Mixer Boss.

The "Kickin' Test"

You fellers in the game now missed something by not meetin' Jim. I ran into him away back in the mountains where we were buildin' a mining village. Jim was one of these impressive lookin' guys. He was tall an' handsome. And on top of that, he wore a goatee and a professor's beard that sort of helped to give his statements a kind of authority by proxy, if you know what I mean. It took a brave man to dispute him.

Well, we had to put up about 200 miners' houses and all the fixin's to make the camp as homey as possible. You pretty near needed a microscope to find enough level ground to build one house, to say nothin' of 200. There was only one way to do it and that was to put the houses on the mountainside with one end of them sticking up in the air on the downhill side. That meant the buildin' of about a thousand, more or less, concrete stilts, some of them more than ten feet high.

Now, this is where the "Kickin' Test" was invented—an' Jim was the inventor. Jim never knew of the colorimetric test for sand an' gravel, to say nothin' of such things as the fineness modulus, even if he did look like a professor. The contractor asked him how about diggin' the aggregate out of the mountain side? Here is where Jim needed his beard an' his air of learnin'.

"Look here," he says, "You put up them darn stilts and I'll tell you if we will accept them when they are finished." An' he walked off with his beard quiverin' in the wind. "But be darn sure they are strong enough," he shot back almost as an afterthought.

There was nothin' to do but put up the stilts—so that is what the contractor did. The gravel an' sand did come out of the mountainside and the contractor was innocent of any idea of reinforcin'. Anyway, about a hundred stilts shot up into the air and the carpenters were getting anxious to set the houses on 'em.

So, with fear and tremblin', the contractor looks up Jim. He recognizes his beard over near the new stilts and says:

"Well, here they are. The carpenters want to get busy."

"Just a moment," comes back Jim with his most educated air, "we gotta test them piers. I have a responsibility to the company that employed me, you know."

Jim said "employed," but I know he was only "hired" just like the rest of us.

The concrete in the stilts was just two days old and the forms had just been removed—lumber had to do double duty here. Jim had a job on his hands an' he knew it. How in blazes was he goin' to test these piers an' make good his "responsibility."

Then an idea hit him. You could tell it by the way he stroked his beard. With a firm step, he walked up to the nearest pier and gave it a good kick. It held! Under the same kind of a kick, the second post fell. There was no question about it—that pier was not up to standard.

That was Jim's contribution to the wide scope of knowledge and learnin' in makin' good concrete and to let other folks know that he was a regular scientist, Jim rides his horse 25 miles to the nearest barber shop and gets his beard trimmed to a point several degrees sharper than before.

Joe, the Mixer Boss.

Organizations

American Concrete Institute; Harvey Whipple, Secretary, 2970 West Grand Blvd., Detroit.

American Concrete Pipe Association; M. W. Loving, Secretary, 33 W. Grand Ave., Chicago.

American Construction Council; Dwight L. Hoopingarner, Executive, 28 W. 44th St., New York City.

American Engineering Standards Committee; Dr. P. G. Agnew, Secretary, 29 West Thirty-ninth St., New York City.

American Road Builders' Association; Wm. H. Connell, President, Miss E. A. Birchland, Secretary, 29 W. 39th St., New York City.

American Society for Testing Materials, C. L. Warwick, Secretary-Treasurer, Engineers' Club Building, 1315 Spruce St., Philadelphia, Pa.

Associated General Contractors of America: D. H. Sawyer Secretary, 1150 Munsey Bldg., Washington, D. C.

Associated Metal Lath Manufacturers; 123 West Madison St., Chicago; Wharton Clay, Commissioner.

Building Officials Conference: H. E. Plummer, President, J. F. Downey, City Hall, Cambridge, Mass., Secretary.

Concrete Reinforcing Steel Institute; M. A. Beeman, Secretary, Tribune Tower, Chicago.

Concrete Products Association; John E. Powers, President, Sterling, Ill.; D. R. Collins, Secretary, 47th and State Streets Alois postoffice, Milwaukee, Wis.

Concrete Products Association of Greater Boston; Glenn T. Hoyt, Secretary, 80 Whitman Ave., Melrose, Massachusetts.

Iowa Concrete Products Association: H. E. Meier, President; R. L. Gavin, Secretary-Treasurer, 405 Hubbell Bldg., Des Moines, Iowa.

National Association of Building Trades Employers; A. E. Coleman, President, 37th St. & Stewart Ave., Chicago. A. W. Dickson, Executive Secretary, 214 Electric Bldg., Cleveland, Ohio.

National Association of Builders' Exchanges; William F. Chew, Baltimore, President; Earl F. Stokes, Secretary, 15 East Fayette St., Baltimore, Md.

National Crushed Stone Association; J. R. Boyd, Secretary, 751 Earle Building, Washington, D. C.

National Housing Association; Lawrence Veiller, Secretary and Director, 105 East Twenty-second St., New York City.

The National Lime Association: Burton A. Ford, Secretary, 927 15th Street, N. W., Washington, D. C.

National Slag Association; H. J. Love, Secretary-Treasurer, 933 Leader-News Building, Cleveland, Ohio.

National Sand and Gravel Association, V. P. Ahearn, Executive Secretary, 432 Munsey Bldg., Washington, D. C.

Nebraska Concrete Products Association; A. V. Anderson, President, Reimers-Kaufman Co., Lincoln, Neb.; E. L. Bateman, Acting Secretary, Bethany, Neb. Annual Convention, Lincoln Hotel, Lincoln, Neb.

Ohio Concrete Products Association; G. M. Friel, Secretary-Treasurer, 2284 North High St., Columbus, Ohio.

Portland Cement Association; William M. Kinney, General Manager, 33 West Grand Ave., Chicago.

Wisconsin Concrete Products Association; A. P. Kuranz, Secretary-Treasurer, 425 E. Water St., Milwaukee.